HARGIS + ASSOCIATES, INC.

CONCEPTUAL SITE MODEL
FORMER MONTROSE AND STAUFFER FACILITIES
AND DOWNGRADIENT AREAS TO LAS VEGAS WASH

HENDERSON,
CLARK COUNTY, NEVADA

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ACRONYMS AND ABBREVIATIONS

ACD	Agricultural Chemicals Division
AMPAC	American Pacific Corporation
ASTM	American Society for Testing and Materials
atm-m^3/mole	atmospheres-cubic meters per mole
BCME	bischloromethylether
bgs	below ground surface
BMI	Black Mountain Industrial Complex
BMI Landfill	Basic Management Incorporated Landfill
BRC	Basic Remediation Company
BHC	benzene hexachloride
CAMU	Corrective Action Management Unit Area
CAPD	Chlor Alkali Ponds
cm/s	centimeters per second
Converse	Converse Consultants, Inc.
CTEH	Center for Toxicology and Environmental Health
CSM	conceptual site model
DAFs	dilution attenuation factors
DCB	dichlorobenzene
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethene
DDT	dichlorodiphenyltrichloroethane
DMPT	dimethyl phosphorodithioic acid
DNAPL	dense non-aqueous phase liquids
DQIs	Data Quality Indicators
ECA	Environmental Conditions Assessment
ECI	Environmental Conditions Investigation
EPA	U.S. Environmental Protection Agency
ERM	Environmental Resource Management, Inc.
ET	Earth Tech
°F	Fahrenheit
f$_{oc}$	fraction organic carbon

<u>ACRONYMS AND ABBREVIATIONS</u> (continued)

ft/d	feet per day
ft^2/d	feet squared per day
GAC	granular activated carbon
Geosyntec	Geosyntec Consultants, Inc.
gpd/ft	gallons per day per foot
gpm	gallons per minute
GWTS	groundwater treatment system
H+A	Hargis + Associates, Inc.
HCL	hydrochloric acid
HDPE	high-density polyethylene
HLA	Harding Lawson Associates, Inc.
K_d	distribution coefficient
K_H	Henry's Law Constant
K_{ow}	octanol-water coefficient
LEM	Lockheed Engineering and Management
LOU	Letter of Understanding
LNAPL	light non-aqueous phase liquids
MCLs	Maximum Contaminant Levels
md	millidarcies
mg/kg	milligrams per kilogram
mg/l	milligrams per liter
MRLs	method reporting limits
mm	millimeter
Montrose	Montrose Chemical Corporation of California
msl	mean sea level
NAPL	non-aqueous phase liquid
NDEP	Nevada Division of Environmental Protection
ng/l	nanograms per liter
Nitrate-N	Nitrate as Nitrogen
NPDES	National Pollutant Discharge Elimination System
OCP	organochlorine pesticides

<u>ACRONYMS AND ABBREVIATIONS</u> (continued)

OSHA	Occupational Safety and Health Administration
PCA	Pioneer Chlor Alkali Company, Inc.
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
PES	PES Environmental, Inc.
pg/l	picograms per liter
PID/FID	photoionization/flame ionization detector
Pioneer	Pioneer Americas, LLC
PRG	Preliminary Remediation Goal
PVC	polyvinyl chloride
Qal	Quaternary alluvium
QAPP	Quality Assurance Project Plan
RCRA	Resource Conservation and Recovery Act
RAS	Remedial Alternatives Study
ROI	radius of influence
Saguaro	Saguaro Power Corporation
SBR	still bottom residues
SECOR	SECOR International, Inc.
SMC	Stauffer Management Company, LLC
SRCs	site-related chemicals
Stauffer	Stauffer Chemical Company
SVE	soil vapor extraction system
SVOCs	semi-VOCs
Syngenta	Syngenta Crop Protection, Inc.
TCB	trichlorobenzene
TCDD	tetrachlorodibenzo-p-Dioxin
TDS	total dissolved solids
TEA	terminal electron acceptor
TEQ	total equivalency
TICs	tentatively identified compounds
Timet	Titanium Metals Corporation

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<u>ACRONYMS AND ABBREVIATIONS</u> (continued)

the Companies	Montrose, SMC/Syngenta, and Pioneer
the Site	Montrose, Stauffer facilities and surrounding area
Tronox	Tronox, Inc.
ug/l	micrograms per liter
UMCc	coarse-grained Upper Muddy Creek Formation
UMCf	fine-grained Upper Muddy Creek Formation
USGS	U.S. Geological Survey
UST	underground storage tank
VEWs	vapor extraction wells
VMPs	vapor monitoring points
VOCs	volatile organic compounds

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HENDERSON,
CLARK COUNTY, NEVADA

<u>EXECUTIVE SUMMARY</u>

This document presents the conceptual site model (CSM) for the current Pioneer Americas, LLC (Pioneer) property ("the Site") and downgradient area to the Las Vegas Wash. The Site and the downgradient area are collectively referred to as the CSM study area (Figure ES-1). The Site incorporates the former Montrose Chemical Corporation of California (Montrose) and former Stauffer Chemical Company (Stauffer) facilities. This CSM was prepared at the request of the Nevada Division of Environmental Protection (NDEP) and is based on both historical information compiled for the former Montrose and Stauffer facilities and extensive site characterization that began in 1979; and current data related to these facilities, Pioneer operations, and the CSM study area.

The Site is located within a heavily industrialized area currently referred to as the Black Mountain Industrial (BMI) Complex and is zoned by Clark County as industrial and manufacturing. The BMI Complex is located within an unincorporated portion of Clark County surrounded by the City of Henderson, Nevada. This CSM was prepared on behalf of Montrose, Stauffer Management Company, LLC/Syngenta Crop Protection, Inc. (SMC/Syngenta) and Pioneer. For the purposes of this CSM, these entities are collectively referred to as "the Companies".

The scope of this CSM included the compilation, organization, integration, and interpretation of relevant facility and study area information and environmental data to meet the following objectives: document historical operations at the Site, identify potential source areas of chemicals, characterize hydrogeologic conditions, delineate site-related chemicals (SRCs) in soil and groundwater, assess transport mechanisms, evaluate exposure pathways and

receptors, and identify data gaps. Responses to CSM-relevant comments from NDEP pertaining to previous study area submittals are also addressed in this CSM.

Historical Site Operations

Montrose manufactured organic chemicals including chlorobenzene, polychlorinated benzenes, chloral, and 4,4'-dichlorobenzil and hydrochloric acid at the Site from 1947 until 1983. Montrose ceased operations at the organic chemical plant in 1983 and demolished the plant in 1984.

Stauffer manufactured chlorine, sodium hydroxide, hydrochloric acid, and agricultural chemical products including pesticides and herbicides at the Site from 1945 through 1984. The Stauffer manufacturing facilities were largely demolished in 1984. Pioneer currently operates chlor alkali production facilities at the Site and manufactures liquid chlorine, caustic soda, hydrochloric acid, and bleach. Pioneer has operated the Site since 1988 following the transfer of ownership from Stauffer.

Adjacent Sites

Several sites are adjacent to the study area. These include:

- The former Basic Management Incorporated Landfill (BMI Landfill) is located adjacent to the northern boundary of the Site, just upgradient of the groundwater treatment system (GWTS) operated by the Companies. The Former BMI Landfill was a waste disposal facility common to the BMI Complex that received wastes from 1942 until it was closed and capped in 1980. The BMI Landfill is currently managed by Basic Remediation Company (BRC) and lies within their proposed Corrective Action Management Unit (CAMU).

- Tronox, Inc. (Tronox; formerly Kerr-McGee Chemical LLC) currently operates an electrolytic chemical manufacturing facility immediately east of the Site (Figure ES-1). Prior to Tronox's operations, Kerr-McGee Chemical LLC manufactured ammonium and sodium perchlorate, among other chemicals, at this facility until about 1997.

- Titanium Metals Corporation (Timet) currently operates an integrated titanium metals production facility immediately east of the Tronox facility (Figure ES-1).

- American Pacific Corporation (AMPAC) operated a perchlorate manufacturing facility southwest of the Site until 1998.

Extensive environmental investigation and remediation programs are ongoing at the Tronox, Timet, and AMPAC facilities to address impacted groundwater downgradient of these sites. The impacted groundwater from these adjacent sites has commingled with impacted groundwater from the former Montrose and Stauffer facilities to varying degrees.

Administrative and Site Investigation History

In 1994, NDEP identified numerous study areas at the former Montrose and Stauffer facilities for environmental investigation. These study areas were typically associated with former manufacturing, materials storage, and waste disposal areas, and as such, are considered the primary potential source areas of chemicals. Potential source areas related to the former Montrose operations include the Former Plant Site, Tank Farm Area, Benzene Storage Tank Area, and the Closed Ponds Area (Figure ES-2). Study areas related to the Stauffer Former Agricultural Chemical Division (ACD) and chlor alkali operations are shown on Figure ES-2. Other areas of interest at the Site include industrial sewer systems, the Inactive Benzene Underground Storage Tanks, and active and inactive wastewater ponds and associated conveyances (Figure ES-2).

Extensive soil and groundwater investigations have been performed at the former Montrose and Stauffer facilities under Consent Agreements with NDEP to characterize soil and groundwater quality. Site investigation activities performed in 2006 and 2007, which form the primary basis for the CSM, included comprehensive soil and groundwater analyses for a broad suite of SRCs, which were formally established in 2006. The SRCs were compiled based on a review of chemicals potentially present at the Site as raw materials, products, wastes, historical sampling results, and miscellaneous other criteria.

Site-Related Chemicals in Soil

Site data indicate that SRCs have impacted soil beneath the former facilities. Surface, vadose zone, and saturated zone soil in the vicinity of former Montrose and Stauffer facilities contain volatile organic compounds (VOCs), semi-VOCs, organochlorine pesticides (OCPs), and metals

above the U.S. Environmental Protection Agency (EPA), Region IX, Preliminary Remediation Goals for industrial soil.

Groundwater Conditions

Groundwater within of the Site is not used as a potential source of drinking water. Hydrogeologic conditions beneath the Site have been characterized to a depth of approximately 300 feet below ground surface (bgs) based on lithologic logs, monitor well construction, water level data, and aquifer testing. Groundwater is first encountered under unconfined conditions within the shallow alluvial sediments (designated as the "alluvial aquifer"). These sediments consist predominantly of unconsolidated silt, sand, gravel, cobbles, and caliche where present within alluvium; and of clay, silt, and fine-grained sand where present within the transition zone or uppermost portions of the Muddy Creek Formation. The alluvial aquifer is typically only a few feet thick in the southern portion of the Site and increases in thickness and grain-size to the north. Saturated conditions extend vertically from the alluvial aquifer into the underlying Muddy Creek Formation to at least a depth of 300 feet bgs.

Groundwater in the alluvial aquifer generally flows to the north in the Site area and to the north-northeast in the area downgradient of the Site. Ancestral paleochannels eroded into the top of the Muddy Creek Formation have been identified on and offsite based on study area drilling. Groundwater elevation data indicate that these paleochannels influence the direction of groundwater flow. This is especially evident near the GWTS, where two distinct paleochannels appear to cause groundwater to converge in this area.

The upper portion of Muddy Creek Formation consists predominantly of saturated, low permeability, unconsolidated to semi-consolidated silt and clay, with occasional thin, laterally discontinuous, interbeds of fine- to medium-grained sand with silt and gravels to a depth of approximately 275 feet bgs. Consistent with regional descriptions throughout the Las Vegas Valley groundwater basin, the upper portion of the Muddy Creek Formation (designated as "fine-grained Upper Muddy Creek Formation [UMCf]") exhibits both the physical and hydraulic properties of an aquitard within the study area. Groundwater within the UMCf is present under semi-confined or confined conditions. Water level data collected in the vicinity of the Site indicate that the general direction of groundwater flow in the UMCf is to the north and an upward vertical gradient exists between the UMCf and the alluvial aquifer.

A deeper coarse-grained zone has been identified within the Muddy Creek Formation at the Site between approximately 275 to 300 feet bgs. This zone consists of saturated, unconsolidated well-graded sand and clayey sand and is designated as the "coarse-grained Upper Muddy Creek Formation" (UMCc). Groundwater within the UMCc occurs under confined conditions and an upward vertical gradient exists between the UMCc and the overlying UMCf and alluvial aquifer.

Site-Related Chemicals in Groundwater

Alluvial Aquifer

Site data indicate that selected SRCs have been detected in alluvial aquifer groundwater at concentrations above EPA Maximum Contaminant Levels (MCLs) including primarily benzene, chlorobenzene, polychlorinated benzenes, chloroform, gamma-benzene hexachloride (BHC), and arsenic (Table 2-1). The SRC total dissolved solids (TDS), which does not have an MCL, has been detected in alluvial aquifer groundwater at concentrations greater than the State of Nevada beneficial use standard for the Las Vegas Wash of 1,900 milligrams per liter (mg/l). Perchlorate, a chemical that is not an SRC, is being monitored because it is present in the groundwater. Perchlorate, which does not have an MCL, has been detected in alluvial aquifer groundwater at concentrations greater than the State of Nevada provisional action level of 18 micrograms per liter (ug/l). SRCs have migrated with alluvial aquifer groundwater primarily by dissolved phase advective transport. Preferential groundwater flow toward and within the paleochannels may also result in prerferrential transport of SRCs. This is especially evident near the GWTS, where the paleochannels appear to cause preferential transport of SRCs in this area based on available water quality data from site investigations.

In general, SRC concentrations in alluvial aquifer groundwater are highest beneath source areas within the study area and decrease significantly across the GWTS area as a result of extraction and treatment of impacted groundwater. Groundwater quality data indicated that the Slit Trench Area within the proposed BRC's proposed CAMU may be a source of selected SRCs to the alluvial aquifer groundwater. The concentrations of SRCs in the alluvial aquifer in the downgradient area are low and typically less than primary or secondary MCLs, with the exception of arsenic and total dissolved solids, respectively, which are not removed from

extracted groundwater by the treatment system, and BHC isomers and chloroform, which may have existed prior to startup of the GWTS.

<u>UMC Zone</u>

Selected SRCs have been detected in UMCf groundwater at concentrations above MCLs including primarily benzene, chlorobenzene, polychlorinated benzenes, chloroform, gamma-BHC, and arsenic. TDS has been detected in UMCf groundwater at concentrations greater than beneficial use standard of 1,900 mg/l. Selected SRCs have been detected several times in the UMCc at the Site, at concentrations above MCLs including arsenic and chromium. Two VOCs were detected above MCLs once in the initial sampling event and these detects were attributed to sampling cross-contamination. Dense non-aqueous phase liquid (DNAPL) has been detected in the UMCf. The DNAPL is composed predominantly of VOCs. The DNAPL exists in the vadose zone, alluvial aquifer, and UMCf, primarily beneath and downgradient of the former Montrose facility as a discontinuous, residual mass; unevenly distributed in the soil matrix in the form of disconnected ganglia to a depth of approximately 120 feet bgs. Further investigation of the horizontal and vertical extent of DNAPL and dissolved-phase SRCs in the UMCf is currently being conducted.

Remedial Actions

Remedial actions implemented at the Site include: 1) the construction and operation of the GWTS; 2) the installation of a soil vapor extraction (SVE) system in the western portion of the Montrose Former Plant Site; 3) the placement of caps over the Montrose Closed Ponds; 4) the placement of asphalt caps over the Former ACD Plant, Former Lindane Plant, and Former BHC Cake Piles 1 and 2; and 5) the placement of clay caps over BHC Cake Pile 3, the ACD Drum Burial Waste Management Area, and the Former Leach Field and Phosphoric Acid Pond/Trenches. The asphalt and clay caps at the former facilities limit the amount of infiltration and reduce potential exposure pathways at these areas of the Site.

The GWTS is located north of the Site, Slit Trenches and BMI Landfill, and has operated since 1983. The GWTS, which recently was extensively renovated and upgraded, currently includes 13 extraction wells, a combination of treatment technologies to remove organic SRCs including air stripping and liquid-phase granulated activated carbon adsorption, and three recharge trenches for the disposal of treated water back to the aquifer system. The recharge trenches

where designed to create a groundwater mound downgradient of the extraction wellfield that provides secondary control of the migration of impacted groundwater. The GWTS effectively captures impacted groundwater from the alluvial aquifer and removes organic SRCs, as demonstrated by the following:

- The system consistently operates at approximately 200 gallons per minute and removes over 8,000 pounds of VOCs annually based on recent performance data. Since 1999, a total of approximately 26,900 pounds of VOCs have been removed from the alluvial aquifer groundwater. Of this total, approximately 19,000 pounds of VOCs (approximately 70 percent) have been removed since the system was renovated and upgraded to improve capture and treatment.

- The substantial decrease in organic SRC concentrations in groundwater downgradient of the GWTS.

- The overlapping cones of depression observed over most of the extraction wellfield during the recent effectiveness evaluation performed at the GWTS. An additional extraction well is planned for the GWTS to improve capture in the central portion of the wellfield.

- The lack of organic SRCs in the treated water injected back to the alluvial aquifer via the recharge trenches.

The SVE system at the Montrose Former Plant Site has operated since 2004 to remove VOCs from impacted soil. To date, this system has removed over 150,000 pounds of VOCs from the soil.

Overall, the remedial actions implemented to date at the Site have been effective at reducing the extent, mobility, and mass of organic SRCs in the soil and groundwater.

Future Land Use and Exposure Pathways

The Site is and has been used exclusively for industrial manufacturing purposes. The Site is expected to continue as an industrial site in the future. Land use downgradient of the Site includes both industrial/commercial and residential areas.

An exposure pathway analysis was performed to identify potentially complete exposure pathways between receptors and SRCs in surface soil, subsurface soil, and groundwater. Potential receptors evaluated in the exposure pathway analysis included indoor and outdoor

onsite workers, trespassers, and offsite residents. Potential exposure routes included inhalation, ingestion, and dermal contact.

Based on the exposure pathway analysis, several potentially complete exposure pathways were identified as summarized in Figure ES-3. Potentially complete exposure pathways for SRCs in groundwater via ingestion and dermal contact may occur if groundwater is used for consumptive purposes in the future.

Data Gaps

A data gap evaluation was performed during the development of this CSM. In general, the data gap evaluation indicated the need for additional focused characterization of SRCs in soil and groundwater, and the character and extent of DNAPL to support future risk assessment, further evaluation of the effectiveness of the existing GWTS, and feasibility evaluations of other potential containment or remedial actions at the Site.

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1.0 INTRODUCTION

This document presents the conceptual site model (CSM) developed for the former Montrose Chemical Corporation of California (Montrose) and former Stauffer Chemical Company (Stauffer) facilities and downgradient area to the Las Vegas Wash. The former Montrose and Stauffer facilities are located within a heavily industrialized area currently referred to as the Black Mountain Industrial (BMI) Complex.   The BMI Complex is located within an unincorporated portion of Clark County surrounded by the City of Henderson, Nevada (Figure 1-1). Presently, the BMI Complex includes property either owned, leased, or administered by Pioneer Americas, LLC (Pioneer), Tronox, Inc. (Tronox), Titanium Metals Corporation (Timet), Chemstar Lime Company, Saguaro Power Corporation (Saguaro), and Basic Remediation Company (BRC) and its affiliates (Figure 1-2).

This CSM is prepared on behalf of Montrose, Stauffer Management Company LLC/Syngenta Crop Protection, Inc. (SMC/Syngenta), and Pioneer. For the purposes of this CSM, these entities are collectively referred to as "the Companies".

1.1 PREVIOUS CONCEPTUAL SITE MODELS

Two CSMs have been prepared previously for portions of the former Montrose and Stauffer facilities. The first CSM was prepared for the entire Pioneer property in 1999, focusing on the former Montrose and Stauffer facilities (the Pioneer property CSM) (Harding Lawson Associates, Inc. [HLA], 1999). The second CSM was prepared exclusively for the former Montrose Closed Ponds Area in 2002 (the Closed Ponds CSM) (SECOR International, Inc.

[SECOR], 2002a). The Closed Ponds CSM was intended to supplement the Pioneer property CSM.

The Pioneer property CSM presented information on facility operations and environmental conditions related to nine potential soil and groundwater contamination source areas, including:

- The Phosphoric Acid Pond and Leach Field;

- The Agricultural Chemicals Division (ACD) Drum Burial Waste Management Area;

- The Former Wastewater Treatment Ponds 1 and 2;

- The ACD Ponds 1 and 2;

- The Former Onsite Leach Beds;

- The Former Lindane Plant, Former Benzene Hexachloride (BHC) Cake Pile Areas 1 and 2, BHC Cake Pile 3, and the Loader Haul Route Area;

- The Benzene Underground Storage Tank (UST) Area;

- The Montrose Closed Ponds, and

- The Montrose Former Plant Site.

Each of these potential source areas was associated with past manufacturing operations and waste disposal practices and was identified as Letter of Understanding (LOU) study items by the Nevada Division of Environmental Protection (NDEP) (NDEP, 1994a and 1994b). These letters provide the foundation of subsequent environmental investigations at the former facilities. The specific LOU study items discussed in the LOU letters for the former Montrose and Stauffer facilities are discussed in more detail in Sections 2.1.3 and 2.1.4.

The Closed Ponds CSM discussed source areas, estimated mass flux from the Closed Ponds Area to groundwater, presented information concerning the distribution and movement of chemicals in subsurface soil and groundwater beneath and downgradient of the Closed Ponds Area, and evaluated exposure pathways (SECOR, 2002a).

The Closed Ponds CSM served as a partial response to NDEP comments to an earlier draft of the document (SECOR, 2002a). The balance of responses to NDEP comments was to be addressed in a revised version of the Pioneer property CSM. However, a revised Pioneer property CSM has not been completed until the development of this CSM.

1.2 PURPOSE AND SCOPE

This CSM was requested by NDEP in a letter to the Companies dated February 16, 2005 (NDEP, 2005). This request was identified by NDEP in the letter as Action Item #3, specifically requesting:

> *Within 30 days, the Companies shall submit a schedule for completing a facility-wide CSM. The CSM should address all impacted and potentially impacted media both on-site and downgradient of the GWTS where contaminants could have come to be located (NDEP, 2005).*

The purpose of this document is to fulfill NDEP's request for a facility-wide CSM. To the extent practicable and reasonable, this CSM was developed in accordance with the *American Society for Testing and Materials (ASTM) International Guide for Developing Conceptual Site Models for Contaminated Sites, E1689-95* (ASTM, 2003). This CSM represents a tool that will provide all stakeholders with a means to better understand environmental conditions within the CSM study area. The scope of this CSM consists of the compilation, organization, integration, and interpretation of relevant facility and study area information and environmental data to meet the following objectives:

- Document historical information and operations at the former Montrose and Stauffer facilities to identify potential source areas where impacts to the environment may have occurred;

- Characterize the hydrogeologic conditions regionally and locally within the CSM study area;

- Delineate the nature and extent of site-related chemicals (SRCs) in the soil and groundwater above background levels;

- Identify the physical, geochemical, and biological processes that control the fate and transport of chemicals in soil and groundwater;

- Understand the historic and currently ongoing remediation efforts;

- Evaluate potential exposure pathways that connect SRCs to potential human and ecological receptors, and

- Identify data gaps where additional information is needed to achieve the objectives listed above.

Much of the content of this CSM as identified by the ASTM guidance has been and will be incorporated into various environmental reports prepared by Montrose, SMC/Syngenta, and/or Pioneer. Therefore, rather than reconstruct extensive sections of previously submitted reports, this CSM will summarize available data from existing reports and the reader will be referred to the original documents that provide the detailed information.

1.3 COMPILATION AND RESPONSES TO PREVIOUS NDEP COMMENTS

NDEP has provided comments to workplans, data submittals, reports, and other work products related to the former Montrose and Stauffer facilities. Specifically, several NDEP comments were issued to the Companies as part of the review of recent soil and groundwater investigation workplans at both former facilities (Hargis + Associates, Inc. [H+A], 2005b and 2006c; PES Environmental, Inc. [PES], 2006a and 2006b).

Because many of the comments were best addressed within the broad range of a CSM, the Companies have agreed to address those NDEP comments related to these workplans and comments from other NDEP letters in this CSM. NDEP comments from 2003 to the present, and inclusive of prior applicable comments, have been compiled and are presented in Appendix A. The compilation is in the form of a tracking table that includes the origination of the comment, the location within this CSM where the comment is addressed, or an explanation of why the comment is not addressed, and a brief synopsis of the response to each comment.

1.4 DOCUMENT ORGANIZATION

This CSM is organized by the following sections:

- 1.0 – Introduction: This section discusses introductory information relevant to the CSM including the purpose, scope, NDEP comment tracking, and use of this document.

- 2.0 – Description of Study Area: This section discusses the CSM study area, presents brief histories of facilities, descriptions of known and potential source areas, describes Site assessment activities conducted to date, and summarizes remedial actions.

- 3.0 – Physical Setting: This section discusses study area climate, topography, surface water, regional geology and hydrogeology, local hydrogeology, and ecology.

- 4.0 Nature and Extent of Chemicals: This section discusses the occurrence of chemicals in background soil and groundwater, the distribution of chemicals in air, soil vapor, onsite soil, onsite and offsite groundwater, dense non-aqueous phase liquids (DNAPL), and presents a qualitative data usability assessment.

- 5.0 Transport Mechanisms: This section discusses transport mechanisms and pathways for study area media including air, soil, surface water, and groundwater.

- 6.0 Groundwater Treatment System Operations: This section discusses the history, current operations, and effectiveness of the remedial Groundwater Treatment System (GWTS) located downgradient of the former facilities.

- 7.0 – Exposure Pathways and Potential Receptors: This section discusses pathways and receptors within the CSM study area.

- 8.0 – Summary of Conceptual Site Model: This section summarizes the current conceptual model based on the available environmental information.

- 9.0 – Evaluation of Data Gaps: This section discusses data gaps identified during the development of the CSM and, in some cases, includes preliminary recommendations for additional environmental investigation work to address data gaps.

- 10.0 – References Cited: This section summarizes all sources of information used in the development of this CSM.

- Appendix A: This appendix includes the compilation of and responses to NDEP comments related to the CSM.

- Appendix B: This appendix includes the data submittal report for the supplemental soil and groundwater investigation work performed at the former Montrose facilities in 2006 and 2007.

- Appendix C: This appendix includes aerial photographs of the former facilities.

- Appendix D: This appendix includes summary tables, maps, and chemical cross-sections for SRCs in soil at the former facilities (Tables D-1 through D-30 and Figures D-1A through D-23).

- Appendix E: This appendix includes summary tables and maps for SRCs in groundwater in the CSM study area (Tables E-1 through E-7 and Figures E-1 through E-13).

- Appendix F: This appendix includes an evaluation of process air emissions for the former Montrose facility.

2.0 DESCRIPTION OF CONCEPTUAL SITE MODEL STUDY AREA

The CSM study area is defined as the southwestern boundary of the BMI Complex extending north to Las Vegas Wash (Figure 2-1). The CSM study area is approximately 2,100 acres in size. The northern portion of the CSM study area, from the GWTS to Las Vegas Wash is also referred to as the downgradient area. The portion of the CSM study area from the Pioneer property to the GWTS is also referred to as the offsite area. The offsite area incorporates ongoing investigation areas including the BRC Corrective Action Management Unit (CAMU) Area and the Basic Management Incorporated Landfill (BMI Landfill), the GWTS, and the downgradient groundwater study area (Figure 2-1).

The property currently owned and operated by Pioneer, formerly occupied by the Montrose and Stauffer facilities, is referred to in this CSM as "the Site" (Figure 2-1). The Site is located in the southern portion of the CSM study area and is approximately 350 acres in size. The former Montrose and Stauffer facilities are administratively separate and distinct from current Pioneer operations. Environmental conditions at the former Montrose facility are being addressed solely by Montrose. Environmental conditions at the former Stauffer facility are being addressed by SMC/Syngenta.

The following sections briefly describe the histories of the former Montrose and Stauffer facilities and ancillary areas. Detailed descriptions of facility designs, construction, operations, waste disposal practices, and decommissioning are presented in Phase I Environmental Conditions Assessment (ECA) documents for each former facility (Converse Consultants, Inc. [Converse], 1993; Roy F. Weston [Weston], 1993).

2.1 HISTORY OF FORMER ONSITE FACILITIES

The Site has been used for the manufacturing of chlor alkali, chemical, and agricultural products since 1942 by Basic Magnesium, Inc., Stauffer, Montrose, and Pioneer (Figure 2-2). Aerial photographs of the Site are included in Appendix C. The Site property is currently operated by Pioneer for the manufacture of liquid chlorine, caustic soda, hydrochloric acid (HCL), and bleach. Various tenants also currently lease parcels of the Site from Pioneer for a variety of industrial and manufacturing operations; the largest is Saguaro, which operates an onsite

natural gas-fired cogeneration facility. The Pioneer property is zoned by Clark County as industrial and manufacturing. The current and projected future land use of the Site is heavy industrial and manufacturing.

2.1.1 Basic Magnesium, Inc.

The Site was first developed in 1941 as part of an industrial complex under a contract with the U.S. Defense Plant Corporation in response to the critical need for the large-scale production of metallic magnesium during World War II. The original industrial complex was operated by Basic Magnesium, Inc., to produce magnesium from 1942 through 1944. There were two major raw materials used to produce magnesium (magnesite and chlorine); and two primary components to the operations; a Chlorine and Caustic Soda Plant and a Magnesium Production Plant. The former Montrose and Stauffer facilities are located at what was the western end of the original industrial complex where the Chlorine and Caustic Soda Plant was constructed (Weston, 1993).

The products of the Chlorine and Caustic Soda Plant operated by Basic Magnesium, Inc. included liquid chlorine and sodium hydroxide. This operation is referred to as the chlor alkali process. Although the manufacturing facilities for the chlor alkali process have been modified over time, both products have been produced at the Site from the early 1940s to present. However, as only the chlorine produced by Basic Magnesium, Inc. was used in the magnesium process; the caustic produced from the Chlorine and Caustic Soda Plant was disposed in Wastewater Ponds 1 and 2 (Figure 2-2). These ponds were also referred to as the Caustic Evaporation Ponds. Wastewater Ponds 1 and 2 were originally constructed by Basic Magnesium, Inc. and were used for the disposal of a variety of process waste streams from the early 1940s onward.

2.1.2 Chronology and Description of Chlor Alkali Operations and HCL Production

The most extensive manufacturing operations that have been conducted at the Site from 1942 to the present day include the manufacture of chlorine, caustic soda, and/or HCL by Basic Magnesium, Inc., Stauffer, Montrose, and Pioneer. The following information provides a brief chronology and general description of the chlor alkali manufacturing operations and HCL production at the Site.

- Basic Magnesium, Inc. constructed and operated the original Chlorine and Caustic Soda Plant at the Site from 1942 through 1945. The products of the Chlorine and Caustic Soda Plant included liquid chlorine and sodium hydroxide. The manufacture of chlorine included the preparation of purified brine which was processed in a Hooker Type S electrolytic chlorine cell to form chlorine gas, sodium hydroxide (caustic), and by-product hydrogen. Although the chlor alkali manufacturing facilities have been modified over time, both products have been produced at the Site from 1942 to present. The caustic produced by the chlor alkali manufacturing facilities was disposed in Wastewater Ponds 1 and 2 (Section 2.1.1). Wastewater Ponds 1 and 2 were subsequently used by Montrose and Stauffer for the disposal of a variety of waste streams.

- From 1946 through 1984, the Site was operated by Stauffer to produce agricultural chemicals. From 1945 through 1988, Stauffer produced chlorine, sodium hydroxide, and HCL (Section 2.1.4) (Weston, 1993). The most extensive of these operations included the manufacture of chlorine and caustic soda from 1945 through 1988, and the production of HCL from 1954 through 1988. In 1976, Stauffer replaced the Hooker Type S electrolytic chlorine cell process with the Diamond Shamrock cell process which continues to be in use today.

- Montrose constructed and operated a manufacturing plant to produce a variety of organic chemicals from 1947 through 1983 (Section 2.1.3). Montrose also constructed a manufacturing plant for the production of synthetic HCL in 1954 and at an expanded facility constructed in 1977 (Converse, 1993). Montrose produced HCL at the Site using two different methods:

  o From 1947 through 1983 as a by-product in the production of chlorobenzene, polychlorinated benzenes, and chloral, and
  o From 1967 through 1981 as a by-product in the production of dichlorobenzil (Converse, 1993).

  Montrose also produced HCL at the synthetic HCL production facilities from 1954 through 1985 when the plant was leased to Pioneer.

- In January 1986, Montrose leased to Stauffer the HCL Plant it owned and operated on property leased from Stauffer. In the mid-1990's, when Pioneer acquired the chlor alkali facility, it became the lessee of the HCL Plant. Pioneer continues to operate the chlor alkali production facilities at the Site for the manufacture of liquid chlorine, caustic soda, HCL, and bleach.

The waste streams generated from the chlor alkali operations have varied over time based primarily on the two different electrolytic chlorine cell designs. The Hooker Type S Cell, in use from 1942 through 1975, was constructed of concrete and included a metal cathode covered with asbestos and a graphite anode. The Diamond Shamrock Cell, in use from 1976 to the present, is constructed of steel and fiberglass and includes a metal cathode covered with asbestos and a titanium anode. The primary waste streams have included (Weston, 1993):

- Brine sludge (discharged via the industrial sewer system to Wastewater Ponds 1 and 2 and Chlor Alkali Ponds (CAPD Ponds) and offsite regulated facility);

- Electrolytic chlorine cell materials (scrap concrete often used for erosion control around the Site, graphite anodes, small amounts of asphalt and lead) disposed in the BMI Landfill;

- Asbestos shavings (drummed for disposal at the BMI Landfill and offsite regulated facilities), asbestos filtrate/rinsate (disposed via the industrial sewer system to CAPD Ponds), asbestos filter cake (disposed at offsite regulated facility), and asbestos sludge (discharged via industrial sewer system to BMI Ponds and offsite regulated facility);

- Chlorine liquefaction sludge (carbon-based impurities from the Hooker Type S Cells combined with chlorine to form mostly chloroform, carbon tetrachloride, and hexachloroethane) disposed in onsite Leach Beds and BMI Landfill (Converse, 1993);

- Spent carbon tetrachloride (Tail Gas Recovery) disposed in the BMI Landfill and offsite regulated facility;

- Sodium hypochlorite waste (discharged via the industrial sewer system to Wastewater Ponds 1 and 2 and CAPD Ponds);

- Sulfate slurry (discharged to either Wastewater Ponds 1 and 2 via the industrial sewer system or BMI Ponds via the Western Ditch, and to CAPD Ponds via the industrial sewer system), and

- Fume scrubber wastes containing a variety of organics and heavy metals (discharged via the Beta Ditch Extension to BMI Ponds).

Montrose reports that waste streams generated from 1947 through 1983 from the manufacture of HCL included impurities of benzene, chlorobenzene, acetaldehyde, chloroacetaldehyde, dichloroacetaldehyde, chloral, chloroform, carbon tetrachloride, spent sulfuric acid, and washwater containing sulfonated metabolites of dichlorodiphenyltrichloroethane (DDT) (Converse, 1993). These wastes were disposed to the industrial sewer system, Wastewater Ponds 1 and 2 or the BMI Ponds, and onsite Montrose Ponds (Figure 2-2).

2.1.3 Former Montrose Facility

Montrose manufactured organic chemicals including chlorobenzene, polychlorinated benzenes, chloral, and 4,4'-dichlorobenzil at the facility from 1947 until 1983. Montrose ceased operations at the organic chemical plant in 1983 and subsequently demolished the plant in 1984

(Converse, 1993). Montrose also manufactured HCL as a by-product of the organic chemical manufacturing process at a synthetic HCL Plant (Section 2.1.2).

From 1947 to 1975, process effluent from Montrose operations and stormwater runoff were discharged to a network of process sewers that ultimately led to the BMI Ponds or to Wastewater Ponds 1 and 2 (Converse, 1993). In 1976, Montrose leased an additional 21 acres from Stauffer at the southern end of what is now the Pioneer property and constructed a series of four lined evaporation ponds, Ponds 1 through 4. A fifth pond, Pond 5, was constructed in 1979 to receive HCL wastes. From 1976 until 1980, Montrose also managed polychlorinated still bottom residues (SBR) at a sixth pond, Pond 6. Ponds 1, 3, 4, and 6 were permanently closed between 1981 and 1989 in accordance with NDEP requirements. Ponds 2 and 5 were permanently closed in 1989 in accordance with federal Resource Conservation and Recovery Act (RCRA) guidelines (Converse, 1993; SECOR, 1997).

The initial basis of the Environmental Conditions Investigation (ECI) Program was outlined by NDEP in correspondence that identified 24 LOU study items for additional investigation (NDEP, 1994a). The early investigation activities focused efforts in a LOU-by-LOU study item manner. However, as the program progressed, certain environmental issues became associated with certain general geographical areas of the former Montrose facilities and the LOU-by-LOU investigation approach became unnecessarily complex. Discussions between Montrose and NDEP in 2001 and 2002 resulted in an agreement to organize further evaluations and investigations on geographical sub-areas that encompass multiple LOU study items of the former facility. These geographical sub-areas of the former facility were named Site Assessment Areas. The Site Assessment Area approach to the ECI field investigation provides the central organizing framework for the ongoing investigation work.

Besides being convenient geographical groupings, the Site Assessment Areas were defined to assist future Remedial Alternatives Study (RAS) activities. As a result of discussions with NDEP, the five Site Assessment Areas delineated for the former Montrose facility are:

- Former Plant Site;
- Closed Ponds Area;
- Former Tank Farm Area;
- Former Benzene Storage Tank Area, and

- Site-Wide Groundwater.

The locations of the Site Assessment Areas are illustrated on Figure 2-2; physical descriptions of the Site Assessment Areas are discussed in later sections. The LOU study items covered by each of the Site Assessment Areas are shown in the following matrix:

SITE ASSESSMENT AREAS/LETTER OF UNDERSTANDING STUDY ITEMS
FOR THE FORMER MONTROSE FACILITY

Site Assessment Area	LOU Study Item No.	Description
Former Plant Site	1	Process Sewer System
	2	Former Organic Chemical Manufacturing Plant Site
	4	Hydrochloric Acid Truck Loading Station
	5	Release from "F"- Storage Tank (1982)
	13	Plant Perimeter Drain Ditch
	14	Stormwater Sewer System
	20	Redwood Tank
	22	Settling Basin
	23	Chlorobenzene Spill (March 1984)
Closed Ponds	6	Spill of Still Bottom Residues (1981) and Still Bottom Residue Storage Tank Area
	15	Ponds 1, 3, and 4 and associated 2-inch Waste Line
	16	Ponds 2 and 5 (RCRA closed ponds)
	17	Pond 6
Former Tank Farm	18	Still Bottom Residue Drum Storage Area
	19	Tank Farm
Former Benzene Storage Tank	3	Railcar Loading Area near Benzene Storage Tank
	21	Benzene Storage Tank on Parcel C
Site-Wide Groundwater	Site-Wide	Site-Wide

The following LOU study items were not included in this consolidation of LOU study items into the five Site Assessment Areas:

- LOU study items No. 7 through 12 requested an evaluation of possible aerial deposition of contaminants from specific air emission sources at the former Montrose manufacturing facilities. The *Evaluation of Process Air Emissions LOU Study Items 7 through 12* document, submitted to NDEP on February 21, 2003, evaluated the possible

aerial deposition from those sources. Although NDEP has not commented on that evaluation as of the date of this document, the conclusion was that the emissions sources posed no significant near-field depositional potential.

- LOU study item No. 24, Demolition Disposal Area, is a fill area located north of Boulder Highway and more than two miles from the former Montrose facility. NDEP believes that some demolition debris from the decommissioning of the Montrose Former Plant Site, not containing process chemicals, was believed to have been disposed in that area. Given the unique characteristics of this LOU item and the distance from the operating areas of the Montrose Former Plant Site, it is being treated as a special case in the ECI Program. A more detailed discussion of LOU item No. 24 will be provided at a later date as an addendum to this CSM.

The five Site Assessment Areas are discussed in the following sections.

2.1.3.1 Former Plant Site

The Former Plant Site was located in the area generally bounded by Avenues G and H to the north and south, and 3rd Street to the east (Figure 2-2). All of Montrose's chemical manufacturing was conducted within the Former Plant Site during the time period from 1947 until 1983. The main plant area was approximately 400 feet long by 300 feet wide and a majority of the process units, consisting of tanks and vessels of various configurations, were located in the western half of the Former Plant Site. Information on the number, capacity, and contents of the process vessels as of 1982 is provided in the Phase I ECA Report (Converse, 1993).

Raw materials used in the manufacturing processes included benzene, chlorine, sodium hydroxide, sulfuric acid, phosphorus trichloride, ethyl alcohol, acetaldehyde, chlorobenzene, and DDT. From these raw materials, Montrose manufactured organic chemicals including chlorobenzene; polychlorinated benzenes including 1,2-dichlorobenzene (DCB), 1,4-DCB, and trichlorobenzene (TCB); chloral; and 4,4'-dichlorobenzil. HCL was also manufactured as a by-product of the manufacturing processes. Similarly ethyl chloride was manufactured as a by-product, but only for a short period of time from 1958 to 1961. Montrose ceased operations at the Former Plant Site, with the exception of the HCL Plant, in 1983 and demolished the Former Plant Site in 1984 (Converse, 1993).

Production of organic chemicals at the facility ceased in 1983 and this portion of the facility was dismantled in late 1983 and early 1984. According to available records, demolition debris

generated by the dismantlement which, based on visual inspection did not appear to be contaminated and which was from areas of the plant that did not handle hazardous materials, was believed to have been disposed at an area located across Boulder Highway and just south of Timet's Pabco Road ponds commonly used for BMI plant demolition materials. This area was unregulated and the approximate location of this area is depicted on Figure 2-1. Recent visual inspections of this area have provided no evidence of the exact location of this area. Montrose also interviewed persons, including former employees, who were unable to identify the area's location. All demolition debris which, based on visual inspection, did appear to be contaminated, as well as all material from any area where hazardous materials or waste were processed or generated, and approximately one foot of underlying soil were disposed of at the U.S. Ecology licensed hazardous waste disposal facility in Beatty Nevada.

2.1.3.2 Closed Ponds Area

The Closed Ponds Area is located in the southernmost portion of the former Montrose facility area (Figure 2-2). The Closed Ponds Area included the following former operational areas:

- Evaporation Ponds 1 through 5 (acidic liquids);
- Pond 6;
- The SBR Storage Tank Area, and
- DCB Storage Tank T-57.

A description of each of these former operational areas follows:

Ponds 1 Through 5

Ponds 1 through 5 were constructed in a seven acre area (Figure 2-2). Liquids were conveyed from the Former Plant Site to the evaporation ponds through two 2-inch diameter conveyance pipelines. These conveyance lines were generally located along the western edge of the individual ponds and perimeter of the ponds area.

Ponds 1 through 4 were placed into service in May 1976. Pond 5 was placed into service in March 1979 to address concerns about air emissions from the mixed liquid previously discharged to the other four ponds. All five ponds were in service through facility closure in

1983 (Figure 2-2). Ponds 1 through 4 were constructed using one 10-millimeter (mm) inner polyvinyl chloride (PVC) liner and one 10-mm outer polyethylene liner. Pond 5 was constructed using a 20-mm inner PVC liner and a 15-mm outer PVC liner. Sand was used as a bedding and leak detection material between the two liner layers at each pond. Gravel-filled drainage trenches were constructed at each end of the ponds to detect leaks in the liner system. The capacity of the ponds varied from two to three million gallons, with each pond being approximately 600 feet long and occupying an area of between one and 2.3 acres, depending on width (Converse, 1993).

Ponds 1, 3, and 4 all received the same material, which included dilute sulfuric acid washwater from the polychlorinated benzene and chloral processes and contained small quantities of DCB, chloral, acetaldehyde, dichloroacetaldehyde, chloroform, carbon tetrachloride, DDT, and phosphorus trichloride. Pond 2 initially received this same sulfuric acid water, but was converted in 1979 to receive overflow from Pond 5, which received HCL water from the chlorobenzene, chloral, and HCL processes. This stream also contained small quantities of benzene, chlorobenzene, chloral, and DCB. Ponds 2 and 5 were classified as RCRA ponds due to the types of materials stored (Converse, 1993; SECOR, 1997).

Following termination of Montrose operations in 1983, the ponds were allowed to dry completely. The sludge remaining at the base of the ponds was then mixed with crushed limestone to neutralize the pH. The ponds were subsequently covered with successive layers of materials, including 12 inches of compacted clay, a 20-mm PVC liner, nine inches of sand, and 12 to 18 inches of native soil. Capping of the ponds was approved by NDEP in May 1987 (Converse, 1993; SECOR, 1997).

During closure of the ponds, a persistent wet area was observed on the north side of Pond 4. In 1988, a trench sump approximately seven feet deep by three feet wide was excavated along approximately 350 feet of the northern border of Pond 4 to collect any free-standing liquids. Characterization of the liquid indicated elevated concentrations of sulfate (Converse, 1993). The liquid that accumulated in the sump was evacuated and transported offsite for disposal. The sump trench has been monitored concurrently with the Post-Closure Groundwater Monitoring Program since pond closure and no free liquids have been detected since 2001.

Pond 6

Pond 6 was located adjacent to the southwest corner of Pond 1 (Figure 2-2). Pond 6 was approximately 100 feet long by 50 feet wide by 10 feet deep and constructed using a single 10-mm polyethylene liner. The pond was placed in service in August 1976 to receive SBR from the chlorinated benzene distillation process. SBR is a highly viscous mixture of chlorinated benzene compounds and is a solid at room temperature. Historical documentation indicates that SBR contained total polychlorinated biphenyl (PCB) concentrations between 0.2 and 0.5 percent by weight, and individual chlorinated benzene compounds between 0.1 and 21 percent by weight (Converse, 1993).

Pond 6 was taken out of service in 1980 and was closed in 1981 under NDEP oversight. PCBs were established as the chemicals of concern for the pond closure, because they were a significant component of SBR and due to their regulated status by the Toxic Substances Control Act (Converse, 1993; SECOR, 1997).

To close the pond, liquids were removed and temporarily stored in tanks or drums. The SBR solids, liner, and underlying soils were excavated and transported offsite for disposal. Approximately 9,800 cubic yards of soil with PCB concentrations exceeding the removal standard of 50 milligrams per kilogram (mg/kg) were reportedly removed from the area. The excavation was backfilled to the surface using compacted soil (Converse, 1993; SECOR, 1997).

Still Bottoms Residue Storage Tank Area

After closure of Pond 6 in 1980, SBR was stored in three aboveground steel tanks located east of Pond 5 (Figure 2-2). The tanks ranged in capacity from 26,000 to 95,000 gallons and were located in a concrete containment area. Only one minor release was documented at this storage area, which comprised a small spill consisting of approximately 20 gallons in 1981 adjacent to the 26,000-gallon storage tank (Converse, 1993; SECOR, 1997).

The SBR Storage Tank Area was demolished in 1983-1984 following termination of facility operations. The tank contents and liquids used for decontamination, including kerosene, were transported offsite for incineration. The storage tanks and concrete containment area were removed, demolished, and removed from the facility for disposal.

Dichlorobenzene Storage Tank T-57

Prior to construction of Pond 5, a 540,000-gallon DCB storage tank was located north of Pond 4 (Figure 2-2). Although records regarding the use of this tank are limited, it was present in this area between 1964 and 1976 based on a review of aerial photographs (Converse, 1993; SECOR, 1997). The aboveground tank was located within diked earthen berms and was apparently demolished to facilitate construction of Pond 5 in the 1978-1979 timeframe. Details regarding the abandonment of this tank are not documented in Montrose records, but it is clear from aerial photos that the tank was located entirely within the area encompassed by Pond 5.

2.1.3.3 Former Tank Farm Area

The Former Tank Farm Area is located in the area generally bounded by Avenue H to the north, the first main line of rail tracks to the south, westward to approximately even with 1st Street, and eastward to approximately the eastern boundary of the Former Plant Site (Figure 2-2). The Montrose facilities located in the Former Tank Farm Area included:

- The Former Tank Farm;

- The SBR Drum Storage Area, and

- A segment of the conveyance lines that ran from the Former Plant Site to the Closed Ponds Area (these conveyance lines were generically referred to as "process sewers" in early ECI documents).

A description of each of these former operational areas follows:

Former Tank Farm

The Former Tank Farm was used to store raw materials. There were 17 individual aboveground tanks in the area, ranging in capacity from 5,200 to 150,000 gallons. No USTs were used in this area. The tanks contained a variety of materials including HCL, benzene, chlorobenzene, DCBs, and acetaldehyde (Figure 2-2). Additionally, two truck or rail car loading/unloading stations for benzene and acetaldehyde were also present in this area. All tanks and loading

equipment were removed from the Site during the closure of the Former Plant Site. The area currently exists as undeveloped land.

Still Bottoms Residue Drum Storage Area

The SBR Drum Storage Area was located approximately 250 feet southeast of the Former Tank Farm (Figure 2-2). The Drum Storage Area was constructed after Pond 6 was closed in 1981 and was used from 1981 to 1983 to store sealed drums containing SBR and other PCB-affected solids. Closure of the area began in February 1983 and was completed in July 1984.

Montrose submitted an amended closure plan to NDEP in September 1987, which reported that all tanks, drums, and concrete had been decontaminated, removed, and transported for offsite disposal (Converse, 1993). The Drum Storage Area was decontaminated using both kerosene-based wet and dry methods. The solid wastes were reportedly transported in bulk containers to the Rollins Environmental Services facility in Deer Park, Texas for incineration (Converse, 1993; SECOR, 1997). The empty drums were reportedly transported to the U.S. Ecology facility in Beatty, Nevada for disposal.

Process Sewers

The term "process sewers" was originally used in past investigation documents to refer to a variety of conveyances at the former Montrose facility that handled process wastes. The only part of the process sewers associated with the Former Tank Farm Area are two parallel two-inch diameter sulfuric acid conveyance pipelines that passed through the Former Tank Farm Area from the Former Plant Site to the Closed Ponds Area to the south (Figure 2-2).

2.1.3.4 Former Benzene Storage Tank Area

The Former Benzene Storage Tank Area is located in a remote location approximately 1,000 feet northwest of the Former Plant Site with the only nearby facilities currently being railroad tracks (Figure 2-2). One 540,000-gallon steel aboveground storage tank was constructed in this area. The tank was situated on a concrete pad surrounded on three sides by berms and was only used for benzene storage. A railcar loading station was present along the southeast side

of the tank. According to Montrose documents, the benzene storage tank was removed from service in 1981 and dismantled between 1984 and 1988. The concrete pad is still present and was found to be in good condition during a Site inspection in October 1991 for the Phase I ECA Report (Converse, 1993).

The Phase I ECA Report indicates that a benzene release from a railcar loading incident in June 1966 may have occurred near the Former Benzene Storage Tank Area (Converse, 1993). However, the historical document describing this incident focused on the actions taken to prevent a reoccurrence and did not address the volume released or the steps taken to clean up the spill. No further information is available regarding this incident.

2.1.3.5 Site-Wide Groundwater

Site-Wide Groundwater conditions for the Site and CSM study area are discussed in detail in Sections 3.0 and 4.0.

2.1.4 <u>Former Stauffer Facility</u>

The Basic Magnesium, Inc. magnesium production plant operated from August 1942 until November 1944 when the U.S. Government curtailed the production of magnesium and the plant was closed. However, the chlorine and caustic production facilities continued to operate. Stauffer signed a lease in May 1945 with the U.S. government to continue the operation of the Chlorine and Caustic Soda Plant. Through a series of subsequent transactions with the U.S. government, Stauffer leased, and in 1952 purchased, approximately 350 acres of property and the Chlorine and Caustic Soda Plant that comprise the current property owned by Pioneer (Converse, 1993).

From 1946 through 1984, the Site was operated by Stauffer to produce agricultural chemicals. From 1945 through 1988, Stauffer produced chlorine, sodium hydroxide, and HCL (Weston, 1993). The most extensive of these operations included the manufacture of chlorine and caustic soda from 1945 through 1988, and the production of HCL from 1954 through 1988 (Section 2.1.2). Stauffer also manufactured the following agricultural chemical products:

- Trithion™ (carbophenothion) and Imidan™ (phosmet) were produced at the Former ACD Plant intermittently from 1958 through 1984 and 1964 through 1976, respectively. These chemicals were produced and sold as insecticides;

- Thiophenol and parachlorothiophenol were also produced at the Former ACD Plant from 1960 through 1984 and 1967 through 1982, respectively. These chemicals were produced as intermediate products for the formulation of pesticides and herbicides manufactured at other facilities, and

- Lindane was produced at the Former Lindane Plant from 1946 through 1958. Lindane was produced as a crystalline product used as an insecticide.

The locations of these former facilities are presented in Figure 2-2.

Starting In 1947, Stauffer subleased and later leased 36 acres of property to Montrose. Montrose constructed plants for the manufacture of organic chemicals and HCL and other ancillary facilities on the leased property including underground benzene storage (Section 2.1.3; Converse, 1993). The various production processes operated by Stauffer and others at the Site since 1942 have resulted in the generation of different waste streams including aqueous organic waste, caustic water, by-products from the production of pesticide products, phosphoric acid, and chlorine cell waste materials. These materials were managed in various waste management areas, both onsite and in the BMI Common Areas, and transported offsite to regulated commercial disposal facilities. From 1945 through approximately 1975, process waste effluent from both Montrose and Stauffer operations and stormwater runoff from the two facilities were discharged into the industrial sewer system. This system included a series of evaporation ponds connected by process piping and surface drainage ditches (Sections 2.1.6 and 2.1.7). In response to the National Pollutant Discharge Elimination System (NPDES) Program that was implemented at the Site in 1975, both Montrose and Stauffer constructed new lined evaporation ponds for the purpose of containing process waste effluent from each respective facility.

The Stauffer former waste management areas are inactive and many of these areas have been capped by constructing either clay or asphalt covers over the respective areas. The active waste management areas at the Site are currently managed by Pioneer under the NPDES Program or are subject to the requirements of other environmental laws or regulations.

As part of the Phase I ECA and Phase II ECI programs performed under the 1996 Phase II Consent Agreement, specific features associated with manufacturing, materials storage, and waste management operations were identified for further environmental assessment and information gathering. These features are referenced in the 1994 Phase II LOU as item Nos. 1 through 32 and are hereafter referred to as LOU Items Nos. 1 through 32. These LOU Items were further deliberated by SMC and Pioneer in the August 8, 1997 submittal to NDEP titled *Response to L.O.U. Information Request* (SMC and Pioneer Chlor Alkali Company, Inc. (PCA), 1997). As a result of discussions with NDEP, the LOU Items identified for further Site assessment (including ancillary site-specific features referenced in NDEP comments) are described below:

- Former Leach Field and Phosphoric Acid Pond (LOU Item No. 4) and Trenches (LOU Item No. 9);

- ACD Drum Burial Waste Management Area (LOU Item No. 5);

- Former Wastewater Ponds 1 and 2 (LOU Item No. 6);

- Inactive ACD Ponds 1 and 2 (LOU Item No. 7);

- Former ACD Plant (LOU Item No. 8);

- Former Lindane Plant (LOU Item No. 10);

- Former Cell Renewal Building Area and Associated Conveyance Facilities (LOU Item No. 11);

- Former BHC Cake Piles 1 and 2, Former BHC Loader Haul Route, and BHC Cake Pile 3 (LOU Item No. 12);

- Inactive CAPD Pond 6 (LOU Item No. 20);

- CAPD Pond 7 (LOU Study No. 21);

- Inactive CAPD Pond 8 (LOU Item No. 22);

- Former HCL/bischloromethylether (BCME) Release Area (LOU Item No. 29), and

- Inactive Benzene USTs (LOU Item No. 30).

The locations of these LOU study items are presented in Figure 2-2.

2.1.4.1 Former Leach Field and Phosphoric Acid Pond/Trenches

Between 1960 and 1970, a portion of the phosphoric acid waste stream generated as part of the thiophenol/parachlorothiophenol manufacturing process, and chlorine liquefaction sludge (between 1958 and 1976) were discharged to the Former Leach Field and Phosphoric Acid Pond/Trenches (Weston, 1993). The Former Phosphoric Acid Pond is located in a portion of the Former Leach Field (Figure 2-2). Between 1970 and 1971, the wastes in these areas were neutralized with lime. It is reported that in 1980, the entire area was capped with a one-foot thick cover of clay, and that an approximate 10-foot deep trench was constructed around the area and backfilled with clay (SMC and PCA, 1997).

2.1.4.2 ACD Drum Burial Waste Management Area

The ACD Drum Burial Waste Management Area is located west of the Former ACD Plant (Figure 2-2). This area was used for the burial of drums containing organic wastes from the manufacture of carbophenothion and phosmet, and phosphoric acid wastes (Weston, 1993). It is reported that in 1980, the entire area was capped with a one-foot thick cover of clay, and that a trench was constructed around the area and backfilled with clay (SMC and PCA, 1997).

2.1.4.3 Former Wastewater Ponds 1 and 2

Former Wastewater Ponds 1 and 2 occupied an area along the northeastern property boundary (Figure 2-2). Active CAPD Pond 7 and Inactive CAPD Pond 8 were constructed over a portion of Former Wastewater Ponds 1 and 2. The two former unlined impoundments were operated from approximately 1943 through 1975 and received various waste streams including those from the thiophenol/parachlorothiophenol and chlor alkali processes (brine sludge and sodium hypochlorite wastes) (Weston, 1993). Additionally, industrial effluent from Montrose operations was discharged to Former Wastewater Ponds 1 and 2 during the time the ponds were in operation (Weston, 1993).

2.1.4.4 Inactive ACD Ponds 1 and 2

Inactive ACD Ponds 1 and 2 were constructed by Stauffer in 1975 and occupy an area along the northwestern property boundary (Figure 2-2). The two ponds are double-lined with a 10-mm polyethylene top liner and a 20-mm PVC bottom liner. The ponds received various process waste streams including those from the thiophenol/parachlorothiophenol, Trithion[TM] (carbophenothion), Imidan[TM] (phosmet), and chlor alkali processes (Weston, 1993). These ponds are currently inactive and receive no process waters.

2.1.4.5 Former Agricultural Chemical Division Plant

The Former ACD Plant operated from 1958 through 1984. Chemicals manufactured at the Former ACD Plant included: thiophenol, parachlorothiophenol, Trithion[TM] (carbophenothion), and Imidan[TM] (phosmet). Ancillary features associated with the Former ACD Plant area included the maintenance shop, drum painting and asphalt spray booth, ACD warehouse, Trithion Plant, vapor-phase incinerator, phosphorus and phosphoric acid storage, phosphorus unloading area, and "waste treatment" area (Figure 2-2). These and other structures associated with the Former ACD Plant were demolished in 1984 (Weston, 1993). An asphalt cap was constructed over the Former ACD Plant area in 2003 and 2004.

2.1.4.6 Former Cell Renewal Building Area and Associated Conveyance Facilities

The Former Cell Renewal Building is reported to have been constructed as part of the original chlor alkali facility by Basic Magnesium, Inc. and was decommissioned subsequent to the replacement of the Hooker Type S electrolytic cell process in 1976 (Figure 2-2). As part of the rebuilding process of the Hooker Type S electrolytic cells, melting pots were used to remove and recycle lead from the graphite anode assemblies. Discarded concrete cell components have been used for erosion control at the Site.

2.1.4.7 Former Lindane Plant

The Former Lindane Plant operated from 1946 through 1958 for the manufacture of lindane (gamma-BHC) (Figure 2-2).   Ancillary features associated with the Former Lindane Plant included the BHC warehouse, Sulfenone warehouse, Karbate coolers basin, and "storage tank". These and other structures associated with the Former Lindane Plant were demolished or removed (Weston, 1993). An asphalt cap was constructed over the Former Lindane Plant area in 2003 and 2004.   The waste by-product from the production of lindane was a solid cake material referred to as BHC cake and was stockpiled in three areas referred to as BHC Cake Piles 1, 2, and 3 (Section 2.1.4.8) (Figure 2-2).

2.1.4.8 Former BHC Cake Piles 1 and 2, Former BHC Loader Haul Route, and BHC Cake Pile 3

BHC isomer cake wastes were stockpiled in three general areas at the Site.   During 1974 through 1976, Former BHC Cake Piles 1 and 2, initially located immediately north of the Former Lindane Plant were removed and consolidated into BHC Cake Pile 3 located west of the ACD Drum Burial Waste Management Area (Figure 2-2).   The Former BHC Loader Haul Route extended from Former BHC Cake Piles 1 and 2 to BHC Cake Pile 3. It is reported that in 1980, BHC Cake Pile 3 was capped, in accordance with NDEP approval, by placement of a one-foot thick layer of clay and an overlying protective cover of sand and gravel (Weston, 1993).

2.1.4.9 Inactive CAPD Pond 6

Inactive CAPD Pond 6 is located immediately south of Former Wastewater Ponds 1 and 2 (Figure 2-2). The pond received a mixture of stormwater runoff and chlor alkali process wastes (Weston, 1993).   Inactive CAPD Pond 6 was constructed with a 20-mm PVC top liner and 10-mm PVC bottom liner, with a leachate collection sump between the liners. Inactive CAPD Pond 6 was closed in accordance with a 1986 Closure Plan approved by NDEP, requiring neutralization to a pH less than 12.5.   In 2000, CAPD Pond 6A was constructed over the western portion of Inactive CAPD Pond 6 (Figure 2-2).

2.1.4.10 CAPD Pond 7

CAPD Pond 7 has operated from approximately 1976 to present and was constructed over a portion of Former Wastewater Pond 1 (Figure 2-2). The pond has received a mixture of stormwater runoff and chlor alkali process wastes (Weston, 1993). The pond is in current use by Pioneer for the collection of stormwater and as an evaporation pond. CAPD Pond 7 is double-lined and equipped with a leachate collection sump used for leak detection monitoring. The original lining system for CAPD Pond 7 included a double-lined 20-mm PVC top liner and a 10-mm PVC bottom liner. In 1981, the pond was relined with a 60-mm high-density polyethylene (HDPE) top liner and 30-mm HDPE bottom liner (Weston, 1993).

2.1.4.11 Inactive CAPD Pond 8

Inactive CAPD Pond 8 operated from approximately 1974 to 1982 and was constructed over a portion of Former Wastewater Pond 2 (Figure 2-2). The pond received a mixture of stormwater and wastewater from both Stauffer (ACD and chlor alkali) and Montrose operations (Weston 1993; Converse, 1993). The pond was double-lined with 20-mm PVC top liner and a 10-mm PVC bottom liner. The pond was removed from service in 1982 due to a breach in the top liner and was subsequently closed in accordance with RCRA requirements and concurrence from NDEP (Weston, 1993).

2.1.4.12 Former Hydrochloric Acid/Bischloromethylether Release Area

A release of HCL combined with an air release of BCME was reported at the Former Trithion™ (carbophenothion) Plant on April 17, 1984. The release of materials included:

- Approximately 1,300 pounds of HCL;
- 6,000 pounds of isoheptane and chemical reaction products, and
- Approximately one pound of BCME (Weston, 1993; SMC and PCA, 1997).

The materials were discharged through a relief line that emanated at the Former Trithion™ Plant and terminated at the "release containment area in the desert" (SMC and PCA, 1997). This area is also referred to as the Former HCL/BCME Release Area (Weston, 1993) (Figure

2-2). Within 24 hours of the incident, soil at the Former HCL/BCME Release Area was neutralized with soda ash and excavated for disposal to an offsite commercial area (Weston, 1993).

2.1.4.13 Inactive Benzene Underground Storage Tanks

Two 40,000-gallon benzene USTs were used historically at the facility to support operations for both Montrose and Stauffer. The Inactive Benzene USTs are located as shown on Figure 2-2. It is reported that 30,000 gallons of benzene leaked from one of the tanks in 1976. The two USTs were subsequently taken out of service and filled with inert materials (Weston, 1993).

2.1.5 <u>Pioneer Chlor Alkali Company Inc.</u>

Pioneer currently operates the chlor alkali production facilities at the Site and manufactures liquid chlorine, caustic soda, HCL, and bleach. Pioneer has operated the Site since 1988, following the transfer of ownership from Stauffer.

Products at the Chlor Alkali Plant are shipped via pipeline, rail cars, and trucks. The process facilities include the brine makeup area, chlorine area, liquefaction area, caustic plant, acid plant, and steam plant. The primary waste streams generated to date by Pioneer are related to the Diamond Shamrock Cell process and associated wastes described in Section 2.1.2. Process recyclable waters and neutralized wastewaters are currently discharged to lined evaporation/containment CAPD Ponds 6A, 7, and 9, and filtered brine mud is disposed in CAPD Pond 2 (Figure 2-2). All other former and existing inactive ponds are reported to receive no process waters. These ponds include CAPD Pond 1, CAPD Pond 3, CAPD Pond 4, CAPD Pond 5, CAPD Pond 6, CAPD Pond 8, ACD Pond 1, and ACD Pond 2.

2.1.6 <u>Process and Storm Sewer System</u>

During initial construction of the Site in the early 1940s, a system of concrete conduits and ditches was constructed at the Site and used by Basic Magnesium, Inc. for stormwater and waste effluent conveyance (Weston, 1993). From 1945 through approximately 1975, process

wastes and stormwater runoff from both the former Montrose and Stauffer operations were collected by and discharged to a common industrial sewer system (Figure 2-2). This system ultimately conveyed these waste streams to Wastewater Ponds 1 and 2 and the upper and lower BMI Ponds (Weston, 1993; Converse, 1993). The industrial sewer system is also referred to in various documents as the process sewer, effluent sewer, plant sewer, and stormwater management system. As summarized below, historical records indicate that the common industrial sewer system used by the former Montrose and Stauffer operations received a variety of waste streams.

- Wastes discharged to the industrial sewer system from Montrose manufacturing operations included: chloride wastes generated from the chlorobenzene production process; HCL wastes and benzene washwater from the chlorobenzene and polychlorinated benzene production process; sulfuric acid wastes from the polychlorinated benzene, chloral, and dichlorobenzil production processes; and process washwaters containing sulfonated metabolites of DDT from the dichlorobenzil production process (Converse, 1993).

- Wastes from the chlor alkali production process discharged to the industrial sewer system included: sodium hypochlorite waste, brine sludge wastes, asbestos slurry wastes, and sulfate slurry waste (Weston, 1993).

- Wastes from the Stauffer ACD manufacturing processes discharged to the industrial sewer system included: aqueous wastes from the thiophenol/parachlorothiophenol, Trithion^{TM} and Imidan^{TM} production processes, caustic wastewater from the thiophenol/parachlorothiophenol production process, and cooling water from the lindane production process (Weston, 1993).

In April 1967, dye tests conducted in the industrial sewer system revealed potential sewer line damage and releases outside of Cell House #2 (Converse, 1993).

In accordance with the NPDES Program that was implemented at the Site in 1975, both Montrose and Stauffer constructed lined evaporation ponds for the purpose of containing process waste effluent from each respective facility. The industrial sewer system was also modified at this time to direct stormwater and wastewater effluent to the onsite lined evaporation pond system, including construction of a concrete diversion box at the northeast corner of CAPD Pond No. 5. Under normal operating conditions, stormwater runoff entering the diversion box flows by gravity to the lined onsite evaporation ponds (Weston, 1993). In accordance with the NPDES permit, stormwater can also be diverted directly to the Beta Ditch Extension, thereby bypassing the evaporation ponds.

The industrial sewer system initially comprised concrete conduits and ditches constructed in the 1940s. The system has been subsequently modified in response to changes in manufacturing processes and disposal locations to be constructed of a variety of materials including vitrified clay, reinforced concrete, transite, cast iron, ductile iron, PVC, and HDPE, with pipe diameters that range from approximately 2 to 42 inches (HLA, 1997). Figure 2-2 illustrates the historical and recent configuration of the industrial sewer system based on available records including:

- Figure 5.2 and Exhibits Q, T, V, and X of Converse, 1993;
- Figure 5-6 of Weston, 1993;
- Figure 1 of Geraghty & Miller, 1990, and
- Drawing GA-44 of SMC and Pioneer, 1997.

2.1.7 <u>Former Ditch Conveyances</u>

From the early 1940s until 1976, process waste effluent from the various operating facilities at the BMI Complex was discharged to the upper and lower BMI Ponds. The following unlined conveyance ditches were used for this purpose: the Alpha Ditch, Beta Ditch, Western Ditch (also termed the Stauffer Effluent Ditch in historical documents [Weston, 1993]), and Northwestern Ditch. These conveyance ditches are described below:

- The Beta Ditch, including the Beta Ditch Extension, was used to convey effluent to the upper and lower BMI Ponds. The Beta Ditch Extension originated near the center of the Site and trended east, skirting the northern boundary of the eastern portions of the BMI Complex where it joined the Beta Ditch which originated at what is now the Tronox facility (Figure 3-3). The Beta Ditch then continued east and northeast under Boulder Highway and eventually connected to the upper and lower BMI Ponds (Weston, 1993);

- The Western Ditch, including the Western Ditch Extension, was used to convey effluent to the lower BMI Ponds. The Western Ditch Extension originated at the northern portions of the Site and trended west across the southern portions of the BMI Landfill property (Figure 3-3). The Western Ditch Extension joined the Western Ditch, which flowed to the north along the western boundary of the BMI Landfill property, and continued north until it connected with the lower BMI Ponds. It is also reported that the Western Ditch may have emptied into the Las Vegas Wash (Weston, 1993);

- The Northwestern Ditch was used to convey effluent to the lower BMI Ponds. The Northwestern Ditch originated at the eastern portions of the BMI Complex at the northern boundary of what is now the Timet facility (Figure 3-3). The Northwestern Ditch flowed

to the northwest and north and connected with the lower BMI Ponds (Weston, 1993), and

- The Alpha Ditch conveyed effluent directly to the Las Vegas Wash. The Alpha Ditch originated northeast of Boulder Highway and flowed to the north, skirting the western portions of the upper BMI Ponds and the eastern portions of the lower BMI Ponds and emptied into the Las Vegas Wash (Figure 3-3).

Commingled waste effluent from both the former Montrose and Stauffer operations was conveyed to both the upper and lower BMI Ponds (Weston, 1993). Waste effluent discharged to the upper BMI Ponds was conveyed via the Beta Ditch Extension and the Beta Ditch. Waste effluent discharged to the lower BMI Ponds was conveyed either: 1) via the Western Ditch, which originated at the northern portions of the Site; or 2) via the Beta Ditch Extension to the Alpha and Beta Ditches east of the Site.

In December 1976, the BMI Complex became a "zero discharge" industrial effluent facility under NPDES, resulting in the discontinuance of the use of these ditch conveyances.

2.2 OFFSITE AREAS

The following sections briefly describe the histories of offsite facilities located within the CSM study area. Detailed descriptions of facility designs, construction, operations, waste disposal practices, and/or decommissioning have been prepared by others (BRC, 2005 and 2007; H+A, 2005a, 2006a, 2006b, 2006d, 2006e, 2006h, 2007a, and 2007b; Geosyntec Consultants, Inc. [Geosyntec], 2007b). These offsite areas include:

- The Former BMI Landfill;
- The GWTS,
- The Downgradient Area, and
- The Demolition Debris Area (LOU Item No. 24).

2.2.1 Basic Management Incorporated Landfill

The BMI Landfill is located north of the Site and south of the GWTS (Figure 2-1). The BMI Landfill is located within the boundaries of property owned and operated by BRC and is bordered by former and present industrial facilities of the BMI Complex.

From 1945 to 1952, a number of private chemical producing companies leased and operated at the BMI Complex under the U.S. Government and then State of Nevada ownership (Weston, 1993; BRC, 2007). The five principal operating companies at the BMI Complex (Stauffer, Western Electrochemical Company [predecessor to Tronox], United States Lime Corporation, National Lead [predecessor to Timet], and Combined Metals Reduction Company) formed BMI for the purpose of owning and operating certain utilities in common to the industrial site. These utilities included electrical and water transmission assets and common disposal areas, including the BMI Landfill and ponds, plant effluent, and storm drainage systems (BRC, 2007).

The BMI Landfill received wastes from 1942 until 1980, at which time it was closed and capped (Weston, 1993). Wastewater effluent from the former Montrose and Stauffer facilities was reported to have traversed the BMI Landfill from approximately 1958 to 1970 via the Stauffer Effluent Ditch or Western Ditch (Section 2.1.7) (Weston, 1993). This effluent was wastewater originating from tank and cell cleanout operations, brine releases, and cooling water flows (Weston, 1993).

Periodically between 1970 and 1980, undocumented process and office waste was also disposed of in slit trenches, located immediately south of the BMI Landfill. There are no records to precisely document the nature of these wastes (BRC, 2005 and 2007). In 2005, BRC performed a field investigation in the vicinity of the BMI Landfill. Based on the aerial photograph review, there appear to be 10 slit trenches that were excavated along east-west trends, with the trenches ranging in length from approximately 450 to 900 feet. Based on direct field observations during drilling operations conducted in 2005, the trenches vary in depth from approximately 25 to 32 feet. Based on a geophysical investigation that was conducted, the width of the trenches is around 20 feet (BRC, 2005 and 2007).

BRC's site assessment investigations in the area of the BMI Landfill included the collection of soil, soil vapor, and groundwater samples; measurement of groundwater levels; and reports to

NDEP (BRC, 2005). High levels of various compounds including benzene, chlorobenzene, chloroform, dioxin, and others have been detected in samples collected from within the landfill and slit trench areas. Data from these investigations and previous work have been compiled in a CSM for the proposed BRC CAMU; an area that includes the footprint of the BMI Landfill (BRC, 2007).

2.2.2 Groundwater Treatment System Area

The GWTS is operated under a Consent Order between the State of Nevada, Stauffer, and Montrose to remediate contaminated groundwater (State of Nevada, 1983). The GWTS has been operating since December 1983. Presently, the GWTS is operated by Pioneer with technical assistance provided by Montrose and SMC. The location of the GWTS is presented in Figure 2-1. The purpose of the GWTS is to extract and treat contaminated alluvial aquifer groundwater migrating northward from the former Montrose and Stauffer facilities and also treats groundwater migrating from the BMI Landfill and slit trenches area. A detailed description of the GWTS is provided in Section 6.0. The GWTS has been effective in mitigating flow of contaminated groundwater into the downgradient area which is described below.

2.2.3 Downgradient Area

The downgradient area extends from the GWTS to the Las Vegas Wash (Figure 2-1). Features that exist in the downgradient area relevant to the CSM include the Tronox Athens Road and Seep groundwater extraction wellfields, the American Pacific (AMPAC) groundwater extraction and treatment system, the City of Henderson Water Reclamation Facility and wastewater rapid infiltration basins, and the lower BMI Ponds.

Recent assessment in the downgradient area consisted of a one-time groundwater sampling event of 22 existing monitor wells conducted on behalf of the Companies in 2006 (Geosyntec, 2007b). The Companies received approval to commence the Downgradient Study from NDEP on March 15, 2006 contingent upon finalizing the respective SRCs list for both the former Montrose and former Stauffer facilities. The monitor wells that were selected for the Downgradient Study were first field-verified in March 2006, then sampled in mid to late July and early August 2006, after obtaining NDEP approval of the combined SRC list.

The first objective of the Downgradient Study was to collect one round of data for both groundwater-level elevations and groundwater quality in the downgradient area. The laboratory analytical program consisted of the combined list of SRCs identified for the former Montrose and Stauffer facilities. This combined SRC list consisted of more than 340 compounds, which required 32 different analytical methods. These 32 analytical methods then included more than 550 compounds in total.

The second objective was to use the results of this downgradient sampling (combined with the recently NDEP-approved quarterly Site-Wide Monitoring Program and other site-related investigations currently being conducted at the onsite former facilities) as input to further develop the ongoing CSM. This program includes several monitor wells in the downgradient area.

In general, very low to non-detectable concentrations for most of the SRCs were found in the downgradient area. Many of the organic compounds that were detected were along the southern and eastern portions of the study area from the southern boundary to about two-thirds of the way to the Las Vegas Wash, with most chemicals being non-detectable closer to the Wash. These overall relatively low values are significant, as these chemicals are present at the former upgradient plant sites and upgradient of the GWTS (Geosyntec, 2007b).

Of particular note is the near absence of benzene, chlorobenzene, organic acids, DDT and DDT isomers among the 22 groundwater monitor wells sampled. Further observations for these and other compounds of particular interest at the Site are as follows:

- Benzene and chlorobenzene were limited to one and three respective detections and were below established Federal Primary Maximum Contaminant Levels (MCLs) for these compounds (5 and 100 micrograms per liter (ug/l), respectively).

- DDT and its isomer compounds (2,4'-dichlorodiphenyldichloroethene [DDE], 2,4'-dichlorodiphenyldichloroethane [DDD], 4,4'-DDE, 4,4'-DDD) were not detected among the 22 groundwater monitor wells sampled.

- The various di- and tri-chlorobenzene compounds were detected sporadically at low concentrations (below Federal Primary MCLs) throughout the downgradient area.

- 4-chlorobenzenesulfonic acid and benzenesulfonic acid were not detected among the 22 groundwater monitor wells sampled. The other three organic acids consisted of diethyl phosphorodithioic acid, dimethyl phosphorodithioic acid (DMPT), and pthalic

acid with 8, 6, and 16 detections at concentrations ranging from 0.05 to 8.5 milligrams per liter (mg/l).

- Both asbestos and white phosphorous were not detected in any of the Downgradient Study monitor wells.

Of the more than 340 SRCs, only four organic and three inorganic chemicals were found to exceed Federal Primary MCLs anywhere in the downgradient study area, with the organic compound exceedances limited to the southern and eastern portions of the study area extending to about two-thirds of the way between the southern downgradient area boundary at the GWTS and the Las Vegas Wash (Geosyntec, 2007b). The chemicals for which these MCLs were exceeded were:

- Arsenic;
- Fluoride;
- Nitrate as Nitrogen (Nitrate-N);
- Gamma-BHC (Lindane);
- Carbon tetrachloride;
- Chloroform, and
- Tetrachloroethene (PCE).

The three inorganic parameters that exceeded their respective Federal Primary MCLs are summarized in more detail as follows:

- Arsenic was prevalent throughout the downgradient area wells at levels exceeding the MCL of 10 ug/l in 16 of the 22 monitor wells sampled. Concentrations of arsenic ranged from 9.4 to 270 ug/l.

- Fluoride concentrations were widely distributed throughout the downgradient area wells within a range of 1.8 to 11 mg/l. Four of the 22 monitor wells sampled had fluoride detections above the established MCL value of 4 mg/l with the higher detections concentrated in the southern portion of the downgradient area.

- Nitrate-N concentrations were evenly distributed throughout the downgradient area wells and were found within a range of 0.65 to 67 mg/l. Eight of the 22 monitor wells sampled had detections above the established MCL value of 10 mg/l for Nitrate-N with the highest detections concentrated in the southeastern portion of the downgradient area.

Of the organic compounds that exceeded MCLs:

- Gamma-BHC slightly exceeded its MCL of 0.2 ug/l in only one well (PC-040) at a concentration of 0.23 ug/l.

- Carbon tetrachloride was found in the downgradient area wells within a range of 0.67 to 11 ug/l and exceeded its MCL of 5 ug/l in three wells. These detections were limited to southern and eastern portions of the downgradient area.

- PCE was found in the downgradient area wells within a range of 0.32 to 6.7 ug/l and exceeded its MCL of 5 ug/l in one well. Overall, PCE detections were distributed more evenly throughout the downgradient area, with the MCL exceedances limited to the southern portion of the downgradient area.

- Chloroform was found in the downgradient area wells within a range of 0.35 to 1,400 ug/l and exceeded the MCL for combined trihalomethanes of 80 ug/l in six monitor wells. The highest concentrations of chloroform occur in the southern and eastern portions of the downgradient area, east of the main paleochannel. The highest chloroform concentration was detected in monitor well PC-067.

Finally, while total dissolved solids (TDS) does not have a Federal Primary MCL, it does have a Federal Secondary MCL value of 500 mg/l. TDS was detected at concentrations ranging from 1,800 to 16,000 mg/l in the downgradient area, with the highest values in the southern and eastern portions of the downgradient area closer to the GWTS and the lower values to the north toward the Las Vegas Wash. TDS values ranged from 2,300 to 2,800 mg/l in the two wells closest to the Wash (Geosyntec, 2007b).

Because a limited number of MCL exceedances and some outlier concentrations were found by this downgradient study, absent any other monitoring program, a reasonable recommendation was proposed to conduct additional monitoring to confirm or refute the findings of this one time monitoring event. The Companies worked with NDEP to establish and implement a Site-Wide Monitoring Program that covers an area from upgradient of the former Montrose and Stauffer facilities through the downgradient area to the Las Vegas Wash (Section 2.3.3.2). This program was implemented in November 2006 and was completed in July 2007.

2.2.4 Demolition Debris Area (LOU Item No. 24)

Production of organic chemicals at the Montrose facility ceased in 1983 and this portion of the facility was dismantled in late 1983 and early 1984. According to available records, demolition debris generated by the dismantlement which, based on visual inspection did not appear to be contaminated and which was from areas of the plant that did not handle hazardous materials, was believed to have been disposed at an area located across Boulder Highway and just south of Timet's Pabco Road ponds commonly used for BMI plant demolition materials. This area

was unregulated and the approximate location of this area is depicted on Figure 2-1. Recent visual inspections of this area have provided no evidence of the exact location of this area. Montrose also interviewed persons, including former employees, who were unable to identify the area's location. All demolition debris which, based on visual inspection, did appear to be contaminated, as well as all material from any area where hazardous materials or waste were processed or generated, and approximately one foot of underlying soil were disposed of at the U.S. Ecology licensed hazardous waste disposal facility in Beatty Nevada. A more detailed discussion of LOU item No. 24 will be provided at a later date as an addendum to this CSM.

2.3 SUMMARY OF SITE ASSESSMENT ACTIVITIES

Montrose and Stauffer environmental programs are conducted within a legal framework governed by Consent Agreements with NDEP (State of Nevada, 1996a and 1996b). The Consent Agreements cover two primary phases of work: the ECI and the RAS. Additional special phases of work, as deemed necessary by NDEP, also are covered; as is a process that provides Montrose and/or Stauffer the opportunity to propose work believed to be necessary to advance the course of the two primary phases of work.

2.3.1 Former Montrose Facility

The following sections briefly summarize environmental investigations conducted at the former Montrose facility to date.

2.3.1.1 Additional Groundwater Investigation Downgradient of the Closed Ponds Area

This investigation evaluated the soil and groundwater conditions along the northern (downgradient) perimeter of the Closed Ponds Area. The investigation included multiple shallow soil borings and the collection of alluvial aquifer groundwater grab samples, the installation of two alluvial aquifer monitor wells, and two short-term aquifer tests (SECOR, 2000).

2.3.1.2 Investigation of Deeper Water-Bearing Zones

This investigation evaluated soil and groundwater conditions of deeper water-bearing zones in the Closed Ponds Area and Former Plant Site. The investigation included installing a deep soil boring and monitor well downgradient of the Closed Ponds Area and Former Plant Site, soil and groundwater sampling, geophysical logging of existing monitor wells, and an aquifer test conducted on the deep monitor well near the Closed Ponds Area (SECOR, 2002b). This investigation provided a starting point for planning further investigation of the fine-grained Upper Muddy Creek Formation (UMCf) (formerly referred to as the second water-bearing zone) and the potential presence of DNAPL.

2.3.1.3 Expedited Investigation Report

This investigation evaluated the hydrogeologic nature of the coarse-grained Upper Muddy Creek Formation (UMCc) (formerly referred to as the third water-bearing zone) based on the installation and groundwater sampling of a deep monitor well north of the Former Plant Site; and water level measurements and groundwater sampling of additional offsite deep Tronox monitor wells. Limited soil sampling was also performed at the Former Plant Site to characterize subsurface soil and materials in the former settling basin (Earth Tech [ET], 2004 and 2005).

2.3.1.4 Additional Limited Groundwater Sampling

Groundwater samples were collected from 10 monitor wells in the former Montrose facility area in August and September 2004. The groundwater samples were analyzed for volatile organic compounds (VOCs) and selected inorganic constituents. The purpose of the groundwater sampling event was to obtain updated water quality data for the alluvial aquifer and UMCf in the Closed Ponds Area and the Former Plant Site (H+A, 2006c).

2.3.1.5 Revised Evaluation of Site-Related Chemicals

Montrose compiled this evaluation of SRCs that could potentially occur at the Site to specifically address NDEP comments. Historic Montrose operations, past practices, and historic analytical data were all considered in this evaluation (ET, 2006). This evaluation provides the basis for

the investigation work needed to fully assess the potential presence of a wide range of chemicals in soil and groundwater at and in the vicinity of the former Montrose facility (Table 2-1).

2.3.1.6 On-Going Montrose Closed Ponds Area Monitoring

Water levels and groundwater samples have been collected from four monitor wells surrounding the Closed Ponds Area since June 1989 as part of RCRA post-closure requirements. Water level measurements and groundwater sampling are conducted biannually. The groundwater samples are currently analyzed for VOCs, organochlorine pesticides (OCPs), and 4,4'-dichlorobenzil. Occasionally, additional organic and inorganic parameters have been analyzed for specific purposes during the monitoring time period (Converse, 2006).

This sampling program provides a long-term record of VOC and other organic compound concentrations along the downgradient perimeter of the Closed Ponds Area as well as upgradient concentrations in groundwater migrating onto the former Montrose facility area from the south (Converse, 2006).

The northeasternmost of the three downgradient monitor wells, MW-2, has exhibited a trend of increasing chloroform concentrations since the 1990's. Concentrations of chloroform have increased from approximately 3,000 ug/l to approximately 96,000 ug/l (April 2008) during this time. These concentrations are indicative of the potential presence of non-aqueous phase liquids (NAPL). A similar trend, although at lower concentrations (41,000 in April 2008) has also been observed at the adjacent downgradient monitor well, MW-3. A more detailed discussion of chloroform concentrations in the Closed Ponds Area including a preliminary evaluation of remedial alternatives has been prepared and submitted to NDEP (Geosyntec, 2008).

Data from the ongoing Closed Ponds Area monitoring indicate that the Montrose Closed Ponds Area is a potential source of VOCs to groundwater. The nature and distribution of VOCs and other SRCs in the Closed Ponds Area is discussed in more detail in Section 4.0 of this document. The CPA will be addressed in future development of remedial alternatives studies for site-wide groundwater and the CPA soils area (Geosyntec, 2008).

2.3.1.7 Supplemental Soil and Groundwater Investigations

The supplemental investigations were a continuation of previous work performed at the former Montrose facility.   Individual workplans were prepared for the soil and groundwater investigations (H+A, 2005b and 2006c). The purposes of the investigations were to:

- Review the extent and distribution of the existing soil and groundwater data;

- Respond to NDEP comments related to subsurface soil and groundwater evaluations from previous Montrose documents;

- Identify data gaps, and

- Plan and conduct a series of field investigation tasks to acquire the information necessary to address the identified data gaps for NDEP's review.

The scope of the investigations included the:

- Collection of more than 130 soil vapor samples at depths from 9.5 to 55 feet below ground surface (bgs) at 33 locations within the Closed Ponds Area.

- Collection of 230 subsurface soil samples at depths from 0.25 to 50 feet bgs at 44 soil borings throughout the former Montrose facility.

- Drilling, construction, and groundwater sampling of four shallow monitor wells located throughout the area of the former Montrose facility.

- Drilling, construction, and groundwater sampling of four deeper monitor wells located in the area of the Former Plant Site.

- Drilling, DNAPL screening, and subsurface soil sampling at eight reconnaissance borings to depths of approximately 170 feet bgs and located downgradient of the Closed Ponds and Former Plant Site Areas.

- Collection of groundwater samples from 31 new and existing monitor wells for Montrose or Stauffer SRCs.

- Performance of two short-term aquifer tests to evaluate hydraulic communication between the two uppermost water-bearing zones in the Closed Ponds Area and Former Plant Site.

The supplemental investigations were conducted between September 2006 and March 2007. The data obtained from the implementation of these supplemental investigations has provided

further definition of the nature of subsurface conditions. These data provide a better understanding of Site environmental conditions and have been used extensively in developing this CSM. A detailed summary of the implementation of the supplemental investigations has been prepared and is included in this CSM as Appendix B.

2.3.1.8 Contingency Dense Non-Aqueous Phase Liquids Reconnaissance Boring Drilling

Evidence of DNAPL was encountered during the drilling of four of the eight deep reconnaissance borings drilled as part of the supplemental investigations (Section 2.3.1.7). Evidence of DNAPL was encountered in boreholes generally north and east of the Montrose Closed Ponds Area and Former Plant Site. Evidence of DNAPL included direct visual observation, reaction with the treated FLUTe® ribbon fabric, elevated photoionization/flame ionization detector (PID/FID) readings, and soil and groundwater sample analytical results. A detailed discussion of DNAPL occurrence is provided in Section 4.4.

In response to these findings, additional contingency drilling was initiated in an effort to delineate the area of DNAPL occurrence. This contingency drilling effort is ongoing as of the date of this CSM. The contingency drilling may consist of up to 10 additional DNAPL reconnaissance borings drilled using rotosonic drilling methods and employing DNAPL screening methods similar to those used during the supplemental investigations. Information collected during the entire contingency drilling program will be transmitted to NDEP at a later date.

2.3.2 <u>Former Stauffer Facility</u>

The following sections briefly summarize environmental investigations conducted at the former Stauffer facility to date.

2.3.2.1 Henderson ACD Plant Groundwater Investigation

Stauffer installed more than 40 monitor wells on what is presently Pioneer property and private land in the vicinity of the GWTS during the period 1971 to 1980 (Geraghty & Miller, Inc., 1980).

The purposes of the investigations were to further define hydrogeologic conditions and the nature and extent of shallow groundwater contamination in the area of the former Stauffer facility. Monitor wells were drilled and installed in areas near Lake Mead Parkway to the south, to an area north of the present day GWTS. Groundwater samples were collected from several of the wells for VOC and other organic compound analyses. Short-term aquifer tests were conducted at selected wells (Geraghty & Miller, 1980).

2.3.2.2 U.S. Environmental Protection Agency Site-Wide Investigations

From 1979 through 1985, Ecology and Environment on behalf of the U.S. Environmental Protection Agency (EPA) performed a series of field sampling programs at the Stauffer facility and offsite areas including the BMI Common Areas. Approximately 28 surface soil/sediment samples and eight subsurface samples were collected at the former Stauffer facility. Approximately 20 of these samples were analyzed solely for dioxin and approximately 16 samples were analyzed for a broader analytical suite including VOCs, semi-VOCs (SVOCs), pesticides, PCBs, and inorganics (Ecology and Environment, Inc., 1989).

2.3.2.3 Pioneer Investigations of Potential Evaporation Pond Locations

From December 1989 through May 1990 Pioneer performed investigations at two areas to assess the suitability for the location of a proposed evaporation pond (Geraghty & Miller, Inc., 1990 and 1991). Seventeen borings were completed in an area south of Inactive CAPD Pond 8 (the eastern screening area) and 20 borings and three test pits were completed east of Inactive ACD Pond 1 and west of CAPD Ponds 4 through 7 (the western screening area; and location of the subsequently constructed CAPD Pond 9).

Borings in the eastern screening area were completed to depths ranging from five to 30 feet bgs and several of the borings were located adjacent to two former drainage ditches, which trend through the eastern screening area. Borings in the western screening area were completed to 20 feet bgs and several of the borings and the three test pits were located adjacent to two pipelines trending across the area. Approximately 50 subsurface soil samples were collected from the 47 borings at depths ranging from approximately five to 21.5 feet bgs and two soil samples were collected from two of the three test pits at unreported depths. Additionally, six

surface soil samples were collected from areas at the northwest portions of the Site to evaluate the suitability of potential spoils material. Approximately 58 soil samples were analyzed for VOCs and tentatively identified compounds (TICs); approximately 57 soil samples were analyzed for OCPs; 54 soil samples were analyzed for SVOCs and TICs; and 23 soil samples were analyzed for metals.

2.3.2.4 Investigation of Saguaro Power Plant Location East of Former ACD Plant

Saguaro performed a Soil and Groundwater Sampling Program in February 1990 as part of a preliminary assessment performed over an approximately six acre area in the eastern portion of the property (Dames & Moore, Inc., 1990). The sampling program included the collection of 22 surface soil samples, 35 subsurface soil samples from 25 borings, and the installation and sampling of four groundwater monitor wells. Eighteen of the borings were completed to depths ranging from five to 10 feet bgs, and seven of the borings were completed to depths ranging from 35 to 60 feet bgs. Approximately 57 soil samples were analyzed for VOCs, OCPs and organophosphorous pesticides, and PCBs and 13 soil samples were analyzed for metals. The area was subsequently converted to a cogeneration power plant.

2.3.2.5 Pioneer Investigation along Natural Gas Pipeline

Pioneer performed soil sampling in November 1990 in preparation of the construction of a new natural gas pipeline (Woodward-Clyde Consultants, 1991). The sampling program included the collection of shallow subsurface soil samples adjacent to an existing natural gas pipeline and railroad tracks located along the western perimeter of the Pioneer property. A total of 11 shallow subsurface soil samples were collected at intervals ranging from 100 to 200 feet apart along the natural gas pipeline. The soil samples were analyzed for a subset of VOCs, SVOCs, and OCPs.

2.3.2.6 Pioneer Investigation at Inactive CAPD Pond 8

In November 1990, Pioneer performed soil and sediment sampling to characterize sediments and subsurface soils within and adjacent to Inactive CAPD Pond 8. A total of six composite

sediment samples were collected within Inactive CAPD Pond 8 and four discrete shallow subsurface soil samples were collected along the perimeter of the pond. The sediment and soil samples were analyzed for selected VOCs, SVOCs, and OCPs.

2.3.2.7 Investigations at Former Lindane Plant, Former BHC Cake Piles 1 and 2, Former ACD
        Plant, and Former Process and Storm Sewer Lines

In response to LOU Study Items 8, 10, 12, and 16, Stauffer and Pioneer implemented a series of vadose zone sampling programs at the Site in 1997 (HLA, 1997). The sampling programs focused on the Former Lindane Plant, Former BHC Cake Piles 1 and 2, Former BHC Loader Haul Route, Former ACD Plant, and Former Process and Storm Sewer Lines.

Soil sampling performed at the Former Lindane Plant, BHC Cake Piles 1 and 2, and the Former BHC Loader Haul Route consisted of the collection of surface and shallow subsurface soil samples from 18 locations to four feet bgs, and the collection of subsurface soil samples at depths extending to 12 feet bgs at three locations. The soil samples were analyzed for BHC isomers. Field screening for surficial BHC was also performed along the Former BHC Loader Haul Route using a field test kit (HLA, 1997).

Stauffer and Pioneer performed two phases of soil sampling at the Former ACD Plant in March and August 1997. The sampling program at the Former ACD Plant consisted of the collection of 19 composite surface soil samples, five composite shallow subsurface soil samples, and one soil boring completed to a depth of 10 feet bgs. The soil samples were analyzed for carbophenothion, phosmet, thiophenol, 4-chlorothiophenol, 1,4-chlorothioanisole, benzene, chlorobenzene, and diethyl disulfide.

Soil sampling performed adjacent to the former process and storm sewer lines consisted of the completion of four soil borings to depths ranging from 14 to 19 feet bgs. The borings were located along Avenue G adjacent to a utility corridor identified as having many process lines. Two borings were located adjacent to the northern boundary of the Montrose Former Plant Site. Eight soil samples were collected from the borings and analyzed for VOCs, SVOCs, and OCPs.

2.3.2.8 Additional Vadose Zone Characterization and Site-Wide Groundwater Sampling Event

SMC/Syngenta and Pioneer conducted additional vadose zone characterization activities to further define surface and subsurface soil conditions and performed Phase I and Phase II site-wide groundwater sampling events in conjunction with Montrose at the former facility in 2006 and 2007 (PES, 2007a and 2007b). The purposes of the investigations were to:

- Assess the potential presence of Stauffer SRCs in surface and vadose zone soil;

- Identify SRCs that may be present to serve as an initial screening for future Site characterization activities;

- Collect current data regarding groundwater level elevations and the distribution of SRCs in groundwater at the Site;

- Further assess the distribution of OCPs, including BHC isomers, in surface soils, and

- Provide additional source area characterization and transport pathway data for this CSM.

The scope of the characterization included:

- The drilling of 14 continuous core vadose zone soil borings and the collection of 56 soil samples from selected depths for analyses of Stauffer SRCs.

- Conversion of five of the 14 soil borings to shallow monitor wells, and the collection of groundwater samples for laboratory analysis of Stauffer SRCs.

- The collection of 145 surface soil samples for laboratory analysis of OCPs.

- The collection of groundwater samples from 21 existing and recently installed monitor wells for laboratory analysis of Stauffer SRCs.

The data obtained from the implementation of this characterization have been used extensively in developing this CSM. Detailed summaries of the results of the Additional Vadose Zone Characterization and addendum have been prepared (PES, 2007a and 2007b).

2.3.3 Joint Investigations

The following sections briefly summarize other ongoing environmental investigations or recently completed investigations conducted jointly by the Companies within the CSM study area.

2.3.3.1 Groundwater Treatment Plant Evaluation Study

SMC, Montrose, and Pioneer conducted an efficiency evaluation of GWTS operations in 1998 (HLA, 1998). Thirty-three monitor wells, including 10 newly installed monitor wells, were sampled either once or twice depending on the results of the first groundwater sampling event for a limited number of target compounds related to the operation and monitoring of the GWTS. The groundwater samples were analyzed for selected VOCs, organic acids, and selected SVOCs (HLA, 1998).

2.3.3.2 Quarterly Site-Wide Groundwater Monitoring Program

The Companies conduct groundwater monitoring on a quarterly basis in the CSM study area. This program is referred to as the quarterly Site-Wide Groundwater Monitoring Program. The purpose of the quarterly Site-Wide Groundwater Monitoring Program is to collect data to assess potential seasonal variations in water level elevations and groundwater chemical concentrations within the CSM study area (H+A, 2006f). Four monitoring events were scheduled beginning in November 2006 through July 2007. Data from this monitoring program through April 2007 was used in the development of this CSM.

The scope of the quarterly Site-Wide Groundwater Monitoring Program includes the measurement of water levels at 52 monitor wells and the collection of groundwater samples from a subset of 38 monitor wells completed in each water-bearing zone in the CSM study area. The number and locations of the monitor wells were selected to provide Site-wide spatial distribution of data to evaluate changes in water levels, contaminant migration patterns, seasonal changes in contaminant concentrations, and concentration changes in the water-bearing zones. Groundwater samples are analyzed for VOCs, SVOCs, OCPs, organic acids, RCRA metals, perchlorate and TDS.

2.3.3.3 Groundwater Treatment System Extraction Well Testing Program

Pursuant to the request of NDEP, the Companies conducted a testing program to evaluate whether the GWTS wellfield was developing overlapping cones of depression (H+A, 2007c).

Preliminary assessment of the drawdown caused by the extraction wellfield was reviewed based on a comparison of static and dynamic water levels. The results of this evaluation indicated that the extent of the cones of depression around extraction wells located in the central area of the wellfield was uncertain.

Based on the evaluation results, four extraction wells located in the central portion of the wellfield were selected for testing. A series of recovery and drawdown tests were conducted on the four GWTS extraction wells in late-2006 and early-2007 to evaluate the extent of drawdown associated with each extraction well and determine if the cones of depression overlap.

A report summarizing the testing results was prepared on behalf of the Companies and submitted to NDEP (H+A, 2007c). This testing showed that the cones of depression overlapped at the test flow rates. However, there were areas in the central portion of the wellfield where full capture was uncertain. NDEP has stated that it does not believe that overlapping cones of depression have been demonstrated in the GWTS area. The efficiency of capture could be improved by adding an additional extraction well in the central portion of the wellfield. The Companies recommended the installation of an additional extraction well in this area (H+A, 2007c) and the installation of the well is planned for the third quarter 2008.

2.3.3.4 GWTS Extraction Well Sampling Program

A program for chemical characterization of the GWTS's extraction well field has been ongoing approximately annually since 2004. In 2006, the scope of the analytical suite used for this program was expanded to include all Stauffer and Montrose SRCs (Geosyntec, 2007c) to obtain a complete characterization of the groundwater pumped from the alluvial aquifer by the GWTS. An additional purpose of this 2006 program was to evaluate these data in the context of previous sampling events to identify trends, if any. Samples were collected from each of the 13 extraction wells in early August 2006.

At the time of the August 2006 sampling, VOCs were detected in every well in the extraction well field, with the highest concentrations entering the eastern side of the extraction well network through Wells F, G, H2, and K2. Forty-three VOCs were detected in at least one extraction well; however, the most prevalent VOCs were benzene, chlorobenzene, and chloroform (Geosyntec, 2007c). Benzene was detected at concentrations from 3.4 to 38,000 ug/l; chlorobenzene concentrations ranged from 0.37 to 30,000 ug/l; and chloroform concentrations ranged from 5.6 to 9,100 ug/l during the August 2006 sampling event (Geosyntec, 2007c).

The presence of organic acids is distributed more evenly across the extraction wells line than the other analyte groups. Concentrations of organic acids detected in the extraction wells ranged from 0.051 mg/l of phthalic acid in Well A to 32 mg/l of 4-chlorobenzenesulfonic acid in Well I (Geosyntec, 2007c). Five analytes contributed to the total detected organic acid concentrations in the extraction wells. Based on the August 2006 data, 4-chlorobenzenesulfonic acid was detected in 11 extraction wells and ranged from 0.23 mg/l to 32 mg/l; benzenesulfonic acid was detected in eight wells and ranged from 0.06 to 3.9 mg/l; diethyl phosphorodithioic acid was detected in 12 wells and ranged from 0.11 to 16 mg/l; DMPT was detected in eight wells and ranged from 2.5 to 20 mg/l; and phthalic acid was detected in seven wells and ranged from 0.051 to 2.4 mg/l (Geosyntec, 2007c).

Based on the August 2006 data, acetaldehyde chloroacetaldehyde and formaldehyde were all non-detectable in the 13 extraction wells sampled (Geosyntec, 2007c).

Based on the August 2006 data, 16 SVOCs were detected in at least one extraction well. The most commonly detected SVOC was 1,4-DCB with a range of 8.9 to 690 ug/l in Well G (Geosyntec, 2007c).

BHC's were present in each extraction well during the August 2006 sampling event, with the higher concentrations detected in the eastern wells. Alpha-BHC was detected in five wells and ranged from 0.17 to 86 ug/l; beta-BHC was detected in all wells and ranged from 0.36 to 36 ug/l; delta-BHC was detected in all 13 wells and ranged from 1.3 to 7.7 µg/l; and gamma-BHC was detected in six wells and ranged from 0.22 to 6.5 ug/l (Geosyntec, 2007c). DDT and its isomers (DDD and DDE) were non detectable in the 13 extraction wells sampled.

Sixteen PCBs were detected in at least one extraction well, during the August 2006 sampling event (Geosyntec, 2007c). The highest PCB concentrations detected were for 2-MonoCB-(1), which was detected in all wells at concentrations ranging from 0.824 nanograms per liter (ng/l) in Well A to 418 ng/l in Well J (Geosyntec, 2007c).

Dioxins and furans were detected in the groundwater samples from each extraction well during the August 2006 sampling event. Nine dioxins and furans are detected in the extraction well network (Geosyntec, 2007c). Calculated total equivalency (TEQ) for all detected dioxin and furan compounds were found to be below the federally established MCL value of 30 picograms per liter (pg/l). The TEQ values for these dioxins and furans ranged between 0 and 1.7 pg/l (Geosyntec, 2007c).

Two components of TPH were detected in one or more extraction wells: extractable fuel hydrocarbons (C8-C40) and volatile fuel hydrocarbons (C6-C12). Extractable fuel hydrocarbons (C8-C40) were detected in 12 wells at concentrations between 0.045 mg/l and 13 mg/l; and C6-C12 was detected in 11 of the 13 wells at concentrations ranging from 43 ug/l to 99,000 ug/l (Geosyntec, 2007c).

TDS is a measure of the dissolved solids of various types in water. These solids include metals (e.g., calcium, sodium, and chromium) and general inorganic compounds, such as alkalinity, chloride, or sulfate. Based on the August 2006 data, TDS concentrations range from 2,600 mg/l in Well B to 32,000 mg/l in Well K2. The higher TDS values were observed in the extraction wells from the eastern part of the network.

During the August 2006 sampling event, pH ranged from 6.96 to 7.53, and 11 inorganic compounds were detected in at least one extraction well. Alkalinity as calcium carbonate, chloride, sulfate and sulfur were detected in all wells at maximum concentrations of 580 mg/l, 16,000 mg/l, 4,300 mg/l and 1,270 mg/l, respectively (Geosyntec, 2007c).

Based on the August 2006 data, 21 metals were detected in at least one extraction well (Geosyntec, 2007c). Of all the metals detected, sodium was detected with the highest concentrations, with detections ranging from 420 mg/l to 9,500 mg/l. After sodium, calcium and magnesium had the highest concentrations, with detections ranging from 140 mg/l to 850 mg/l

and 70 mg/l to 900 mg/l, respectively. Additionally, arsenic is detected in each of the wells in the extraction well network at concentrations ranging from 92 ug/l to 270 ug/l (Geosyntec, 2007c).

The extraction well sampling program, using a reduced analyte list relative to the 2006 program is ongoing on an annual basis to track concentration changes across the wellfield for operational purposes.

2.3.4 Investigations Conducted by Others

The following sections briefly discuss environmental investigations conducted by others in and near the CSM study area that are relevant to the preparation of this CSM. These investigations have been reviewed and data collected as part of the investigations have been used to supplement the data collected by Montrose and SMC/Syngenta for this CSM.   These investigations are described below.

2.3.4.1 Tronox Investigations

The Tronox site is located adjacent and immediately east of the Pioneer property (Figure 1-2). BMI Complex area geologic, hydrogeologic, and chemical fate and transport mechanisms for the Tronox site were reviewed as part of the development of this CSM (ENSR, 2005). Tronox has drilled and installed several monitor wells as part of ongoing groundwater investigation activities to characterize and remediate areas of groundwater impacted with perchlorate and hexavalent chromium. Lithologic, water level, and water quality data have been made available by Tronox for review of the development of the CSM. The specific data used includes: 1) lithologic data from monitor wells and borings have been used to help define the location and orientation of paleochannels on top of the Muddy Creek Formation that may provide preferential flow patterns in the alluvial aquifer, and 2) water level and water quality data from selected monitor wells completed in the alluvial aquifer and Muddy Creek Formation to assist in defining groundwater flow conditions and the distribution of chemicals in these units. Tronox monitor wells located throughout the Site and CSM study area are presently used as part of the quarterly Site-Wide Groundwater Monitoring Program (Section 2.3.3.2).

2.3.4.2 Timet Investigations

The Timet site is located in the eastern portion of the BMI Complex (Figure 1-2). BMI Complex area geologic, hydrogeologic, and chemical fate and transport mechanisms for the Timet site were also reviewed as part of the development of this CSM (ENSR, 2005). Timet has drilled and installed several monitor wells as part of ongoing groundwater investigation activities to characterize and remediate areas of groundwater impacted with inorganic constituents. The specific data used includes: 1) lithologic data from monitor wells and borings have been used to help define the location and orientation of paleochannels on top of the Muddy Creek Formation, and 2) water level and water quality data from selected monitor wells completed in the alluvial aquifer to assist in defining groundwater flow conditions.

2.3.4.3 BMI Landfill Investigation

The BMI Landfill is located within the CSM study area immediately north of the Pioneer property line extending to the southern boundary of the GWTS (Figure 2-1). BRC conducted a soil and groundwater investigation in the area of the Former BMI Landfill in 2005 (BRC, 2005). The soil and groundwater investigation consisted of exploratory borings, surface and subsurface soil sampling and analysis, the drilling and installation of monitor wells completed in the lower portions of the alluvial aquifer and the uppermost portions of the Muddy Creek Formation, groundwater sampling, and data interpretation. BMI Landfill area geologic, hydrogeologic, and chemical fate and transport mechanisms were reviewed and incorporated into this CSM (BRC, 2007).

Lithologic, water level, and water quality data from these investigations have been incorporated into this CSM. The specific data used includes: 1) lithologic data from monitor wells and borings have been used to help define the location and orientation of paleochannels on top of the Muddy Creek Formation that may provide preferential flow patterns in the alluvial aquifer, and 2) water level and water quality data from selected monitor wells completed in the alluvial aquifer and Muddy Creek Formation to assist in defining groundwater flow conditions and the distribution of SRCs in these units in the area between the Site and the GWTS. BRC monitor wells located near the BMI Landfill are presently used as part of the quarterly Site-Wide Groundwater Monitoring Program (Section 2.3.3.2).

2.4 SUMMARY OF REMEDIAL ACTIONS

Remedial actions initiated by Montrose and/or Stauffer and Pioneer within the CSM study area include:

- The construction and operation of the GWTS since 1983;

- The installation of a soil vapor extraction (SVE) system in the western portion of the Montrose Former Plant Site (Figure 2-2);

- The placement of an asphalt cap over the Former ACD Plant, Former Lindane Plant, and Former BHC Cake Piles 1 and 2; and 4) the placement of soil covers over BHC Cake Pile 3, the ACD Drum Burial Waste Management Area, and the Former Leach Field and Phosphoric Acid Pond/Trenches, and

- Other remedial actions potentially affecting the CSM study area.

The following sections briefly summarize these remedial actions conducted in the CSM study area to date.

2.4.1 Groundwater Treatment System

The GWTS is located north of the former Montrose and Stauffer facilities and south of the downgradient area (Figure 2-1). The purpose of the GWTS is to extract and treat contaminated alluvial aquifer groundwater migrating northward from the former Stauffer and Montrose facilities and BMI Landfill areas. Contaminated groundwater is extracted from the alluvial aquifer by 13 extraction wells. The flow from selected extraction wells having elevated concentrations of VOCs is routed through a carbon adsorption unit to reduce the VOC load on the downstream air stripper. The pre-treated groundwater is then combined with extracted groundwater from the remainder of the extraction wells and treated using air-stripping followed by activated carbon adsorption. The treated groundwater is then returned to the alluvial aquifer downgradient of the extraction wells via three below-grade recharge trenches. The GWTS has been operating since 1983. A detailed discussion of GWTS operations and effectiveness in mitigating flow of contaminated groundwater further downgradient is presented in Section 6.0.

2.4.2 Montrose Former Plant Site Soil Vapor Extraction System

ECI soil investigations in 1996 and 1997 indicated the presence of elevated concentrations of VOCs beneath portions of the Montrose Former Plant Site. In August 2003, an SVE pilot test was conducted to evaluate the feasibility of removing VOCs from permeable vadose zone from this area. The pilot test demonstrated the effectiveness of SVE by removing vapor-phase VOCs at an approximate rate of 244 pounds per day from a single pilot test well. In 2004, a Full-Scale SVE Program was initiated as an interim remedial action for accelerating remediation of the Montrose Site through removal of VOCs from permeable soils. Currently, the system is being augmented with additional capability in conjunction with NDEP review and approval.

2.4.2.1 Description of the SVE System

A figure illustrating the location and components of the SVE system has been prepared (Figure 2-4). A positive displacement rotary lobe blower is used to extract soil vapors from the subsurface at a design flow rate of 1,000 standard cubic feet per minute and a vacuum of 15 inches of mercury. VOC-impacted soil vapors are extracted from the subsurface through four vapor extraction wells (VEWs) and an aboveground piping network. Moisture condensate is removed from the vapor stream by a centrifugal-type moisture separator. Soil vapors are then passed through four vessels connected in series, each containing 5,000 pounds of granular activated carbon (GAC) located within the treatment system compound. The VOCs are removed from the vapor stream by carbon adsorption prior to discharge under an air permit from the Clark County Department of Air Quality Management. As GAC vessels become saturated with VOCs over time, the spent carbon is routinely replaced with virgin coconut shell carbon prior to resuming SVE operations.

Four VEWs and three vapor monitoring points (VMPs) have been drilled to date (Figure 2-4). VEW-1 and the three VMPs were installed as part of the 2003 SVE pilot test. VEW-1 was installed in the northwest corner of the Montrose Former Plant Site where elevated VOC concentrations were previously detected between 5 and 40 feet bgs. The three VMPs were installed at varying distances, up to 80 feet, and directions from VEW-1 for purposes of monitoring vacuum influence during pilot testing.

The placement of the other three VEWs was based on soil data collected as part of the ECI Program and the results of the 2003 SVE pilot test. The VEWs were installed in the northern and western portions of the Montrose Former Plant Site where vadose zone soils were known to be impacted with elevated concentrations of VOCs. The spacing of the VEWs was based on a minimum radius of influence (ROI) of 87 feet determined during the 2003 SVE pilot test with some overlapping as a conservative approach for ensuring adequate vacuum influence throughout the VOC-impacted area. VEW-2 was installed in the north-central portion of the Montrose Former Plant Site where elevated VOC concentrations were previously detected at 10 feet bgs. VEW-3 and VEW-4 were installed in the western portion of the Montrose Former Plant Site where elevated VOCs were previously detected between 5 and 40 feet bgs.

VOCs and some SVOCs are routinely extracted by the SVE system. The most commonly detected vapor contaminants at the SVE system and their concentrations from each of the four VEWs are summarized as follows:

Vapor Contaminant	Vapor Concentration (ppmv) in Samples Collected March 19, 2007			
	VEW-1	VEW-2	VEW-3	VEW-4
VOCs				
Benzene	<8.4	140	920	670
Carbon Tetrachloride	<8.4	21	160	160
Chlorobenzene	270	1,100	1,800	2,900
Chloroform	<8.4	26	180	120
SVOCs				
1,2-DCB	55	180	120	<59
1,3-DCB	<8.4	<19	<24	<59
1,4-DCB	92	330	230	65

< = not detected above reporting limit
ppmv = parts per million by volume

2.4.2.2 Soil Vapor Extraction System Operations

The initial startup of the SVE system occurred on September 7, 2004. Limited and intermittent operation of the SVE system continued through the first quarter of 2005 as part of the startup and testing activities. Long-term SVE operations were initiated on April 7, 2005 and continue as of this report date. Through the first quarter of 2007, the SVE system has operated for a total of 9,635 hours and removed an estimated 73,761 pounds of vapor-phase contaminants as total non-methane organic compounds.

A significant reduction in vapor concentrations has been observed at all four VEWs since initial startup of the SVE system. Through the first quarter of 2007, the percent reduction in concentrations for the four primary VOCs detected at the VEWs are as follows:

Vapor Contaminant	Percent Reduction in Concentration Since Baseline Conditions			
	VEW-1	VEW-2	VEW-3	VEW-4
Benzene	100%	97%	66%	95%
Carbon Tetrachloride	100%	98%	91%	98%
Chlorobenzene	88%	93%	42%	78%
Chloroform	100%	98%	91%	94%

Baseline conditions are from September 9, 2004
Characterization Issues Related to SVE Program Data

The SVE system has been successful in removing a significant mass of VOCs from the vadose zone below the Montrose Former Plant Site. The VOC contaminants and relative concentrations detected during the SVE Program are consistent with those detected in soils during the ECI Program in 1996 and 1997. Due to their lower vapor pressures, SVOC contaminants are detected at comparably lower concentrations by the SVE Program. Additional soil characterization data collected in December 2006 as part of the Supplemental Soil Investigation confirms that VOC concentrations have been significantly reduced in shallow soils at many locations demonstrating the effectiveness of the SVE Program.

The Supplemental Soil Investigation characterization data indicates the presence of VOCs outside the design ROI of the VEWs east and southeast of VEW-3 and VEW-4. Additional VEWs are proposed to address these areas as well as two other locations, within the design ROI, where elevated VOCs were detected. The SVE system infrastructure (wells and piping) will be expanded to address the revised extent of VOC impacts to vadose zone soils.

2.4.3 Asphalt Cap Over Former ACD Plant, Former Lindane Plant, and Former BHC Cake Piles 1 and 2

In 2003 and 2004 Stauffer constructed an asphalt cap over an approximately six-acre area of the Site, including the Former ACD Plant, Former Lindane Plant, and Former BHC Cake Piles 1 and 2. The asphalt cap serves to limit the amount of infiltration and reduce potential exposure pathways at these areas of the Site.

2.4.4 <u>Soil Covers Over BHC Cake Pile 3, ACD Drum Burial Waste Management Area, and the Former Leach Field and Phosphoric Acid Pond/Trenches</u>

Available records indicate that soil covers consisting of a one-foot thick clay cover ("clay soil cover"), overlain by approximately one foot of native sand and gravel deposits ("surface cover layer") were installed over BHC Cake Pile 3, the ACD Drum Burial Waste Management Area, and the Former Leach Field and Phosphoric Acid Pond/Trenches (Weston, 1993). Available information related to the construction of the soil covers at each of the three areas is summarized below:

- Available records regarding details of the BHC Cake Pile 3 (Stauffer, 1987; Weston, 1993) indicates: "During 1978-1979, the remaining BHC cake pile (BHC Cake Pile 3) was closed by filling to grade with sludges removed from Wastewater Pond 1 during the construction of CAPD 7 and capping with a clay cover"; the dimensions of the capped area are reported to be approximately 250 feet by 450 feet. It is further reported that the "proposed cover system was to include a protective cover over the clay cap composed of local sand and gravel type soils" (Weston, 1990). According to information provided in the August 8, 1997 *SMC Response to L.O.U Information Request*: "Although the drawing indicates a planned clay thickness of 6 inches, this specification was apparently changed to an installed 12 inches as noted in a letter report by Weston dated May 1, 1990 which evaluated the effectiveness of the cap"; and "The ECA report [Weston, 1993] noted that the clay material to be used for the cap had a test permeability of 8.85×10^{-7} centimeters per second (cm/s). This information was provided to the State of Nevada via a letter dated May 2, 1980 from Stauffer which included laboratory testing from a "R.C. Harlan and Associates". The letter was prepared in response to a letter from the State dated March 6, 1980 which approved the plan for closure [i.e., disposal] of the BHC pile while requesting information on the clay layer permeability and other data."

- Available records regarding details of the ACD Drum Burial Waste Management Area (Stauffer, 1987; Weston, 1993) indicates: the area was closed and capped in October 1980 with a one-foot thick clay cover and encircled by a trench filled with clay possessing an average permeability of 8.85×10^{-7} cm/s; and the "dimension of the capped area is approximately 200 feet by 500 feet". It is further reported (Weston, 1993) that "The drum burial closure technique and clay used was the same as used for the BHC area [(described above)] and was conducted at about the same time."

- Available records regarding details of the Former Leach Field and Phosphoric Acid Pond/Trenches (Stauffer, 1987) indicates: the wastes in the area of the Former Phosphoric Acid Pond and Trenches were neutralized with lime and alkaline soil; the area was "closed and capped in October 1980"; the "dimension of the capped area is approximately 200 feet by 500 feet"; and the area was "covered with a clay cap and encircled a 10 foot [deep] trench filled with clay." It is further reported (Weston, 1993) that the "phosphoric acid pond closure technique and clay used was the same

as used for the BHC area [(described above)] and was conducted at about the same time."

A scope of work to assess conditions of the existing soil covers at each of the three aforementioned areas was implemented in August 2007 in accordance with the May 31, 2007 *Work Plan for Assessment of Soil Covers, Former Stauffer Chemical Company Facility, Henderson, Nevada, NDEP Facility ID H-000536* (PES, 2007c). The objectives of the scope of work are to collect data to assess the current physical characteristics of the soil covers (i.e., surface topography, horizontal and vertical extent of cover materials, and geotechnical parameters of soil cover materials) and compare with available historical information regarding the construction of these soil covers. The data will also be used to further document the soil cover specifications and to provide an update of current conditions. The scope of work included: 1) the completion of 65 surface soil borings and nine soil cover profile borings to measure and assess the physical characteristics of the soil cover materials; 2) the collection of seventeen soil samples for laboratory analysis of geotechnical parameters, metals, and OCPs; and 3) performing a high-definition topographic survey (also known as three-dimensional laser scan) of the ground surface at each of subject waste management areas. The results of the assessment will be provided to NDEP under separate cover in accordance with the schedule described in the May 31, 2007 Work Plan (PES, 2007c).

2.4.5 Other Remedial Actions Potentially Affecting the CSM Study Area

Groundwater remediation systems are present in and near the CSM study area. Tronox maintains three groundwater remediation systems designed to capture and treat shallow groundwater containing elevated concentrations of chromium and perchlorate. These three systems include the following:

- On-Site Cut-off Wall and Interceptor Wellfield (located immediately east of GWTS): This system consists of a 1,600-foot long and 60-foot deep slurry wall and 23 upgradient extraction wells. This system typically extracts and treats impacted groundwater at a rate of approximately 70 gallons per minute (gpm).

- Athens Road Well Field (located in the downgradient area midway between GWTS and Las Vegas Wash): This system consists of 14 extraction wells located within an approximately 1,000-foot wide paleochannel incised within the Muddy Creek Formation. Impacted groundwater is extracted and treated at a rate of approximately 270 gpm.

- <u>Seep Area Collection System (located adjacent to Las Vegas Wash)</u>: This system consists of a surface capture pump and 10 extraction wells located in the extreme northern location of the downgradient area. Impacted groundwater is extracted and treated at a rate of approximately 620 gpm.

The remediation systems utilize fluidized bed reactor methods to remove perchlorate and iron reduction to remove hexavalent chromium from groundwater (ENSR, 2005). The location of the Tronox remediation systems are presented in Figure 2-1.

AMPAC also operates two groundwater remediation systems to capture and remediate shallow groundwater containing elevated concentrations of perchlorate. The AMPAC remediation systems utilize in-situ bioremediation to remove perchlorate from impacted groundwater. The locations of the AMPAC remediation systems are presented in Figure 2-1.

3.0 PHYSICAL SETTING

The Site is located within the BMI Complex, approximately 12 miles southeast of Las Vegas (Figure 1-1). The Site and CSM study area are located within section 36 of Township 21 South (T21S), Range 62 East (R62E); sections 1, 2, 11 through 14 of T22S, R62E, section 6 of T21S, R63E, and section 31 of T22S, R63E.

The Pioneer property, which encompasses the Site, is approximately 350 acres in size. The CSM study area, including the Pioneer property, is approximately 2,100 acres in size or slightly less than three square miles. The Site is located within an unincorporated area of Clark County. The downgradient area is located within the City of Henderson. Included in the downgradient area is the residential community referred to locally as Pittman, and other residential, commercial, and light industrial properties (Figure 2-1).

3.1 CLIMATE

The Las Vegas-Henderson area climate is arid (Malmberg, 1965). Daytime high temperatures in the summer are extreme and are often above 100 degree Fahrenheit (°F). Winters are considered mild. Average annual temperatures range from a high of approximately 80°F to a low of approximately 56°F (National Oceanic & Atmospheric Administration, 2007).

Precipitation averages slightly less than 4.5 inches per year. In general, precipitation occurs during the winter months of December through March, and during the summer months of July through September. Winter storms are characterized as being sustained and of low intensity. Summer storms often occur as thunderstorms of high intensity and brief duration causing significant surface overland flow. Potential evapotranspiration is significantly greater than average precipitation, ranging from approximately 60 to 82 inches annually (Southern Nevada Water Authority, 1996).

3.2 TOPOGRAPHY

The CSM study area is located along alluvial fan deposits derived principally from the McCullough Range located to the south (Figures 3-1 and 3-2). As such, land surface elevations across the CSM study area slope significantly from the south to the north ranging from a high elevation of approximately 1,870 feet above mean sea level (msl) along Lake Mead Parkway, to approximately 1,770 feet msl at the northern boundary of the Site, to approximately 1,540 feet above msl along Las Vegas Wash in the extreme northeastern portion of the CSM study area (U.S. Geological Survey [USGS], 1983).

Land surface slopes at an average gradient of approximately 0.02. In general, this slope is relatively constant. However, breaks in this gradient occur within the CSM study area just north of the GWTS, where the average gradient decreases to approximately 0.014 from south to northeast. Land surfaces have been altered to accommodate historic and current facility operations and processes, stormwater control, and residential and/or commercial developments. Examples of these areas include the former Montrose and Stauffer facility operational areas, the current Pioneer manufacturing areas and ponds, and the community of Pittman (Figure 3-1).

3.3 SURFACE WATER

The entire Las Vegas Valley is drained by Las Vegas Wash. Las Vegas Wash discharges to Las Vegas Bay and then Lake Mead. Near the CSM study area, Las Vegas Wash is perennially flowing in response to stormwater runoff, shallow groundwater discharge, and receipt of treated effluent from a variety of city and county sources and treated groundwater from the Tronox facility groundwater remediation systems.

There are no naturally occurring, perennial surface water bodies located within the CSM study area. Surface water is occasionally present as stormwater runoff in some undeveloped portions of the CSM study area during and after precipitation events. Surface water drainage features within the CSM study area direct surface water toward Las Vegas Wash. The majority of the CSM study area is unpaved and sparsely vegetated. Ground surface features that reduce the infiltration of surface water and divert water to natural and anthropogenic drainage features

include paved and capped areas, in addition to industrial, commercial, and residential developed areas.

3.3.1 Current Surface Water Drainage Features

Natural drainage features present in both the northern and southern portions of the Site are limited to shallow drainage courses that are dry except during short periods following intense precipitation events. Three stormwater conveyance ditches are present within the southern portion of the Site (Figure 3-3) which direct surface water runoff to a municipal stormwater catch basin located west of the property.

Surface water runoff in the central portion of the Site (including the chlor-alkali and HCL plants, Former Stauffer ACD and Lindane operation areas, and Montrose Former Tank Farm) is collected and managed as part of the Pioneer stormwater management system. The area of the Montrose Former Plant Site is also protected with a concrete curb around the perimeter to divert runoff from entering that area. Surface water runoff in the northern portion of the Site is contained by an earthern berm that extends along much of the northern property boundary, with the exception of the northwest area, where the berm is breached by shallow drainage courses, which allow offsite runoff. Conveyance ditches located in the northeast section of the Site are inactive with the exception of the Beta Ditch, which occasionally receives overflow from the stormwater system during large storm events (Section 2.1.7).

Drainage features in the offsite CSM study area are predominately anthropogenic including the municipal stormwater system which consists of a series of storm drains, catch basins, culverts, concrete-lined channels, and swales which drain toward Las Vegas Wash.

3.3.2 Historical Surface Water Drainage Features

Historical surface water drainages from the McCullough Range south of the Site appeared to have existed prior to development. USGS topographic maps and historic air photos indicate the presence of intermittent streams upgradient of the Site that are presently diverted around the BMI Complex (USGS, 1984; Lockheed Engineering and Management [LEM], 1980). Intermittent streams were also located to the west of the property (USGS, 1984; LEM, 1980).

These streams are no longer present as these areas have become developed and modified by anthropogenic features.

From 1945 through approximately 1975, stormwater runoff generated in the central portion of the Site was discharged into the industrial sewer system. This system included a series of evaporation ponds (CAPD Ponds 6, 7, and 8, and Former Wastewater Ponds 1 & 2) connected by process piping and surface drainage ditches (Sections 2.1.6 and 2.1.7). Runoff in the northern portion of the Site was also diverted to the Beta Extension Ditch, and/or the Northwestern Drainage Ditch. The runoff of surface water from the southern portion of the site followed topographic relief to the west.

3.4 REGIONAL GEOLOGY AND HYDROGEOLOGY

The CSM study area is located in the Las Vegas Valley. The Las Vegas Valley is a northwest-southeast trending structural trough located within the Basin and Range physiographic province (Malmberg, 1965; Plume 1989). The Basin and Range province is characterized by uplifted fault-blocks forming the surrounding mountain ranges, alternating with down-dropped blocks forming sediment-filled valleys.

The mountain ranges bounding Las Vegas Valley in the study area include Frenchman Mountain to the northeast, which is comprised of Paleozoic and Mesozoic sedimentary rocks (limestone, dolomite, sandstone, and siltstone), and the McCullough Range to the south, which is comprised of Tertiary volcanic rocks (basaltic and andesitic lava flows, flow breccia, and ash-flow tuff). Further to the west and east, the Las Vegas Valley is bounded by the Spring Mountains and Sunrise Mountains, respectively. The Las Vegas Valley, which locally contains up to 13,000 feet of Tertiary and Quaternary basin-fill sediments and volcanic flows and deposits, is interpreted to have largely formed through right-lateral movement along the Las Vegas Shear zone (located approximately four miles north of the Site) (USGS, 2005).

The valley-fill sediments in Las Vegas Valley consist of Miocene to Pliocene Muddy Creek Formation and younger sediments (Plume, 1989). The valley fill is reported to be several thousand feet in thickness and comprise the primary water-bearing zones in Las Vegas Valley. In general, the primary source of potable water is within coarse-grained deposits which

comprise the "deep aquifer" or "principal aquifer" generally from 300 to 2,000 feet bgs. However, in the central and eastern parts of Las Vegas Valley, clays and silts predominate in lieu of the transmissive coarse-grained deposits (Plume, 1989). Where present, the deep aquifer is overlain and confined by a regional aquitard which is several hundred feet thick. Groundwater which is often present within the upper portion of the regional aquitard or overlying alluvium (i.e, upper thirty feet of saturated sediments) comprises the "shallow aquifer", and is not considered a source of potable water in Las Vegas Valley. In most areas of Las Vegas Valley, water quality of the shallow aquifer exceeds standards for potable water due to elevated concentrations of TDS which exceed 1,000 mg/l (Plume, 1989; Las Vegas Valley Water District, 1991).

In general, the valley fill within the east and southeast parts of Las Vegas Valley (vicinity of the CSM study area) is comprised of predominantly fine-grained deposits interbedded with thin intervals of coarse-grained and heterogeneous deposits that are not laterally continuous (Plume, 1989); the exception being where near surface coarse-grained deposits are present along the Valley margins. The aggregate thickness of these fine-grained deposits is reported to be at least 500 feet in the vicinity of the study area (Plume, 1989).

Additionally, a series of north-south to northwest-southeast trending faults have been mapped within the fine-grained Tertiary and Quaternary valley-fill deposits in the central and southern portions of Las Vegas Valley. These intra-valley faults within the fine-grained deposits are reported to form discontinuities and barriers to groundwater flow (USGS, 2005).

3.5 HYDROGEOLOGY OF CONCEPTUAL SITE MODEL STUDY AREA

Generalized hydrogeologic cross-sections showing the primary hydrogeologic units that comprise the groundwater system within the CSM study area have been prepared based on available information obtained from monitor well drilling within the CSM study area (Figures 3-4 through 3-11A). Soil boring and well construction data have also been provided (Tables 3-1 and 3-2).

The two primary lithostratigraphic units that comprise the groundwater system in the CSM study area include the Quaternary Alluvium (Qal) fan deposits and the underlying Muddy Creek

Formation. The Qal fan deposits typically consist of sands, gravels, and cobbles with varying amounts of silts and clay. The underlying Muddy Creek Formation consists of clays and silts with lesser and varying amounts of fine-grained sand and gravels.

The Qal deposits have been deposited unconformably on an erosional surface present that forms the top of the older, northward sloping Muddy Creek Formation. The Qal deposits originate from the McCullough Range south of the Site and are therefore thickest, approximately 50 to 65 feet, in the southern portions of the Site. The Qal deposits generally thin to approximately 35 feet in thickness in the northern portion of the Site. The Qal deposits may also be locally thicker along erosional channels, or paleochannels, on the surface of the Muddy Creek Formation. In the Site and CSM study area, the Qal deposits consist predominantly of sands and gravels with varying amounts of silt, and occasional cobbles. The Qal deposits are locally cemented with caliche, predominantly near the contact with the underlying Muddy Creek Formation.

Recent drilling conducted by Montrose and SMC/Syngenta indicates the presence of a reworked or "transition zone" of fine-grained sediments near the base of the Qal deposits. These fine-grained sediments are interpreted as reworked sediments (primarily clays and silts) from the underlying finer-grained Upper Muddy Creek Formation that have been redeposited within coarser-grained sediments and caliche at the base of the Qal. The transition zone exhibits characteristics of both the Qal and upper portions of the Muddy Creek Formation. The thickness of this transition zone varies significantly, generally ranging from not present to 25 feet. Similar sediments have been identified at the Timet facility to the east and is referred to as the transitional Muddy Creek Formation (Timet, 2007b).

The Muddy Creek Formation is comprised of basin-fill sediments deposited in an alluvial system. The sediments are generally coarser-grained near the mountain fronts and grade to progressively finer-grained deposits near the center of the valley (Plume, 1989). Beneath the investigated areas of the Site to a depth of about 275 feet, the Muddy Creek Formation consists principally of clays and silts interbedded with thin, sporadic deposits of fine- to medium-grained sand or mixtures of clayey, silty sand. These sporadic interbeds range in thickness from one to three feet. Between approximately 275 and 300 feet bgs a coarser-grained interval or facies of the Muddy Creek Formation has been identified beneath the Site and the adjacent Tronox facility, as further described in Section 3.5.3, below. Coarse-grained deposits of the Muddy

Creek Formation are also reported to be at or near the surface along the southern boundaries of the Tronox facility east of the Site and the former AMPAC facility west of the Site (ENSR, 2005).

The depth to the top of the Muddy Creek Formation ranges from approximately 35 feet in the northern portion of the study area and in the area of the GWTS, to approximately 65 feet in the southern portion of the Site. The Muddy Creek Formation has been identified beneath the Site area to a depth of at least 300 feet bgs based on lithologic data collected during the drilling of a deep monitor well located approximately 750 feet north of the Montrose Former Plant Site (ET, 2005). The lithologic log in the vicinity of the Site indicates that the total thickness of the Muddy Creek Formation is reported to extend to a minimum of 2,158 feet bgs (Environmental Resource Management [ERM], 2003).

Groundwater is present within the Qal deposits and Muddy Creek Formation at the Site and within the CSM study area. Previous investigations and reports prepared for the CSM study area have referred to the saturated Qal fan deposits as the alluvial aquifer and various depth zones within the Upper Muddy Creek Formation as the second water bearing zone and the third water bearing zone. However, describing these sub-units of the groundwater system as different water bearing zones implies that there is hydraulic separation of these sub-units and implies that the second water bearing zone is an aquifer that contains distinct coarser units within Muddy Creek Formation that are traceable over the CSM study area. The data collected to date do not support this concept. The data collected to date during construction of borings and monitor wells in the Upper Muddy Creek Formation indicate that the sediments are predominantly finer-grained and no laterally extensive layers or lenses of coarse-grained materials have been identified to a depth of approximately 275 feet. The lithologic and hydraulic data collected from the monitor wells indicate the upper 275 feet of the Upper Muddy Creek Formation exhibits the physical and hydraulic characteristics of an aquitard, rather than an aquifer. This is consistent with the regional hydrogeologic setting described in available literature for the Las Vegas Basin and summarized above in Section 3.4.

Similarly, the UMCc (previously described third water-bearing zone) appears to be no more than a sequence of coarser-grained deposits within the Upper Muddy Creek Formation that extends from a depth of approximately 275 to a depth of at least 300 feet. Thus, for this CSM report, and future reports, the alluvial aquifer, UMCf and the UMCc will be used to describe the sub-units within the upper 300 feet of the hydrogeologic regime.

The following sections discuss the nature of these sub-units. Descriptions of these sub-units are primarily based on the results of recent drilling and sampling programs conducted by the Companies in 2006 and 2007 and recent water level and water quality data collected from the quarterly Site-Wide Groundwater Monitoring Program (Appendix B; H+A, 2006f). Historical data also have been used to supplement the recently collected information.

3.5.1 <u>Vadose Zone</u>

Lithologic data from borings and monitor wells completed in the CSM study area indicate that the vadose zone consists predominantly of the coarse-grained Qal sediments from land surface to approximately 30 to 60 feet bgs (Figures 3-4 though 3-6, and 3-12). This zone is underlain by a sequence of fine-grained sediments, which corresponds to either a transition zone between the Qal deposits or the Muddy Creek Formation.

Based on physical samples analyzed as part of pilot testing activities for the Montrose Former Plant Site SVE system, significant differences in measured permeabilities exist between the coarse-grained and fine-grained sediments. Measured horizontal and vertical permeabilities for the coarse-grained, upper vadose zone materials are reported to be 862 and 432 millidarcies (md), respectively (ET, 2005). Measured horizontal and vertical permeabilities for the underlying fine-grained materials are reported to be 30.6 and 5.89 md, respectively. These measurements illustrate the differences in permeability between the two vadose zone lithologies.

Under the CSM study area the thickness of the vadose zone decreases to the north toward Las Vegas Wash. Based on water level measurements collected by the Companies during 2006 and 2007, the thickness of the vadose zone ranges from approximately 45 feet in the southern portion of the study area near the operating facilities to approximately 5 feet near the northern boundary of study area (Table 3-3).

3.5.2 <u>Alluvial Aquifer</u>

Groundwater within the CSM study area is first encountered within saturated sediments near the base of the Qal deposits, in the transition zone between the Qal deposits and underlying Muddy

Creek Formation, or in the uppermost portions of the underlying Muddy Creek Formation, and is referred to as the alluvial aquifer (Appendix B; PES, 2007a).

The alluvial aquifer is predominantly composed of unconsolidated silt, sand, gravel, and cobbles with interspersed lenses and nodules of caliche where present within the Qal deposits; and of clay, silt, and fine-grained sand with interspersed lenses and nodules of caliche where present within the transition zone or uppermost portions of the Muddy Creek Formation (Appendix B; PES, 2007a). The alluvial aquifer is typically only a few feet thick in the southern portion of the Site, increasing in thickness and generally becoming coarser-grained to the north in the area of the GWTS (Figures 3-7 through 3-11).

3.5.2.1 Groundwater Movement, Water Levels, and Aquifer Characteristics

Groundwater movement in the alluvial aquifer is predominantly from the south to the north. A groundwater level contour map using data from November 2006 has been prepared (Figure 3-13). Groundwater level data from November 2006 represents the most readily available comprehensive data set for the CSM study area to date. North of the GWTS, groundwater movement is slightly to the northeast to Las Vegas Wash. Groundwater within the alluvial aquifer flows to the north at gradients ranging from approximately 0.01 to 0.02 based on water level data collected from November 2006 to the present.

The direction of groundwater movement within the alluvial aquifer appears to be influenced by the slope and erosional features of the upper surface of the Muddy Creek Formation (Figure 3-14). The surface of the Muddy Creek Formation slopes predominantly to the north at a gradient of approximately 0.01 to 0.03 based on a review of lithologic logs prepared for borings and monitor wells in the CSM study area. Erosional features, or paleochannels, have been identified on the surface of the Muddy Creek Formation particularly in the area of the GWTS and downgradient areas (Geosyntec, 2007b). The paleochannels are typically narrow and elongated and locally influence the direction of groundwater movement in the alluvial aquifer to the northeast in the northern portion of the CSM study area toward the Las Vegas Wash (Figure 3-14). Figure 3-14 was prepared by contouring the depth to the top of the Muddy Creek Formation using data from logs of soil borings, monitor wells and extraction wells within the

CSM study area, and supplemented with information from previous reports by BRC and Tronox (BRC, 2007; ENSR, 2005).

Groundwater occurs in the alluvial aquifer predominantly under unconfined conditions based on the fact that no confining unit has been identified during the drilling of alluvial aquifer monitor wells, and there is no observed rise in the water level from the depth at which groundwater was first encountered during drilling of alluvial aquifer monitor wells at the Site (Appendix B).

Depths to groundwater measured in alluvial aquifer monitor wells typically range from approximately 40 to 75 feet bgs at the Site and five to 25 feet bgs in offsite downgradient areas (Table 3-3). Seasonal fluctuations of groundwater levels generally range from one to two feet in both the onsite and offsite areas. Based on groundwater level data collected from November 2006 to July 2007, changes are typically within one to two feet on a quarterly basis (Table 3-3). Hydrographs depicting CSM study area groundwater level conditions have been prepared (Figures 3-15 through 3-21). A figure illustrating the saturated thickness of the alluvial aquifer has also been prepared using groundwater level elevations measured during the third quarter of 2006 and the top of the Muddy Creek Formation determined from monitor well boring logs (Figure 3-22).

Along the eastern boundary, in the central and northern portion of the CSM study area, east of the GWTS, the alluvial aquifer is absent where the top of the Muddy Creek Formation is higher than the water table (Figure 3-22). As indicated above, the top of the Muddy Creek Formation is an erosional surface and in this area the Muddy Creek Formation is less eroded and the Qal is thinner and is not saturated.

Alluvial aquifer testing was conducted in the Site area, north of the Montrose Closed Ponds Area in 1999 (SECOR, 2000). The aquifer tests consisted of falling- and rising-head slug tests conducted at alluvial aquifer monitor well PW-1 (Figure 3-4). Hydraulic conductivity was estimated at approximately 3.5 to 5.1 feet per day (ft/d) based on the results of the slug tests. Based on the estimated saturated thickness of approximately 1.5 feet, the transmissivity ranged from approximately 5 to 7 feet squared per day (ft^2/d) (SECOR, 2000). The estimates of hydraulic conductivity from the slug tests are within the range of reported aquifer hydraulic conductivity values in the literature for similar materials (fine- to medium-grained sand and silt) (Freeze and Cherry, 1979).

Short-term aquifer tests were conducted at eight alluvial aquifer monitor wells located in the GWTS area in 1982. The aquifer tests were conducted as part of the GWTS siting investigation (Stauffer, 1983). The purpose of the aquifer tests was to obtain estimates of alluvial aquifer transmissivity, storage, and permeability in support of determining the location and design of the GWTS. Aquifer testing activities included:

- Eight short-term, single well tests;
- Four slug tests, and
- Three long-term multiple well tests (Stauffer, 1983).

Results of the aquifer test analyses provide reliable estimates of aquifer parameters for the alluvial aquifer in the GWTS area. Estimates of the transmissivity of the alluvium generally ranged from 8,300 to 35,200 gallons per day per foot (gpd/ft) (approximately 1,100 to 4,700 feet squared per day [ft^2/d]) across the GWTS area (Stauffer, 1983). These aquifer test results indicate that the alluvium is coarser and more transmissive in the GWTS area compared to the Site area.

Short-term aquifer tests also were conducted at four extraction wells located at the GWTS in 2006-2007. The aquifer tests were conducted as part of a GWTS effectiveness evaluation (H+A, 2007c). The results of the aquifer test analyses indicate that the transmissivity of the alluvium in the GWTS area is approximately 5,000 to 6,000 gpd/ft (approximately 670 to 800 ft^2/d) in the vicinity of extraction wells J and D2 and approximately 12,000 to 17,000 gpd/ft (approximately 1,600 to 2,300 ft^2/d) in the vicinity of extraction wells C and E3, respectively. The hydraulic conductivity of the test zone (predominantly alluvium) near extraction wells J and D2 is estimated to be approximately 60 to 80 ft/d assuming a nominal, static saturated thickness of 10 feet for this area. The hydraulic conductivity of the alluvial aquifer near extraction wells C and E3 is estimated to be approximately 60 to 90 ft/d assuming a nominal, static saturated thickness of 25 feet for this area. These aquifer test results are in good general agreement with those estimated in 1982 and also indicate that the alluvium is coarser, thicker, and more transmissive in the GWTS area compared to the Site area.

3.5.3 Upper Muddy Creek Formation Fine-Grained Deposits

Underlying the alluvial aquifer is the UMCf (previously referred to as the second water-bearing zone).   In the Site area, the UMCf consists predominantly of unconsolidated to semi-consolidated silt and clay, with occasional interbeds of fine- to medium-grained sand with silt and gravels (Appendix B). These interbeds are typically between one and three feet thick and appear to be discontinuous throughout the formation, as they are encountered at varying depths in boring to boring (Appendix B). Caliche is present, typically near the contact between the alluvial aquifer and the Upper Muddy Creek Formation and in the transition zone. The best descriptions of caliche come from boring logs prepared for wells drilled using the rotosonic drilling method where the type of caliche and the characteristics of the caliche can be observed. The information from these boring logs typically describe the occurrence of caliche as various forms of caliche inclusions in the soils such as; nodules, granules, fragments, disseminated caliche, concretions, veins or caliche rich zones (Appendix B).   In a few localities such as in borings RB-02, RB-07, RB-08, and RB-14 layers of caliche are described. These layers are described as ranging in thickness from 1/8 inch to less than one foot (Appendix B). However, no continuous layers of caliche were observed even in closely spaced borings such as in the borings constructed in the Closed Ponds and the Former Plant Site Areas. Thus, the data collected to date do not indicate that extensive caliche layers and horizons exist in the study area.

North of the Site (i.e., beneath the proposed BRC CAMU), the UMCf is also predominantly comprised of silt and clay to a depths of approximately 200 feet bgs (BRC, 2007).

3.5.3.1 Groundwater Movement, Water Levels, and Hydraulic Characteristics

To date, seven UMCf monitor wells are present in the Site area (Figure 3-5). These monitor wells are completed at varying depths within the UMCf and are located over a limited area. Although a detailed water level contour map can not be constructed with the present set of wells, examination of water level data measured as part of Site-wide quarterly monitoring suggest that the movement of groundwater is from south to north, similar to that of the alluvial aquifer (Figure 3-23).

The data collected to date in the CSM study area indicate the UMCf is saturated and that groundwater in the UMCf is in hydraulic connection with the alluvial aquifer. This conclusion is based on observations made during drilling and the results of aquifer testing conducted in the UMCf and as described below and in Appendix B. These conclusions and observations are consistent with the hydrogeologic conditions in the UMCf described by others within the BMI Complex (Timet, 2007b).

Groundwater occurs in the UMCf under confined or semi-confined conditions. Groundwater levels rise in monitor wells completed in the UMCf to levels above the top of the Muddy Creek Formation (Appendix B). Depths to water measured in UMCf monitor wells typically range from approximately 35 to 60 feet bgs in the Site area (Table 3-3). In most locations, groundwater elevations determined at monitor wells completed in the UMCf are approximately five to 10 feet higher in elevation compared to groundwater elevations at nearby alluvial aquifer monitor wells. This indicates that an upward vertical gradient exists between these zones. Water levels in UMCf monitor wells fluctuate very slightly in the Site area. Based on water level data collected from November 2006 to July 2007, changes in water levels generally vary within one foot on a quarterly basis (Table 3-3). Hydrographs depicting CSM study area water level conditions have been prepared (Figures 3-15 through 3-21).

As indicated above, aquifer testing was conducted in the UMCf north of the Montrose Closed Ponds Area in 2000 (SECOR, 2002b). The aquifer testing consisted of a step-drawdown test conducted at UMCf monitor well CP-1 located north of the Montrose Closed Ponds Area. Estimates of transmissivity were determined during the various steps of the test with a geometric mean of 140 gpd/ft (approximately 19 ft^2/d). Based on the estimated saturated thickness of approximately 1.5 feet, hydraulic conductivity was estimated at approximately 12 ft/d (SECOR, 2002b). This estimated hydraulic conductivity value for the UMCf is not considered valid due to the nature of the aquifer test (i.e., step-test only), limited duration of the tests, lack of observation wells in the UMCf to monitor actual aquifer response, constraints imposed by the low yield of the well, minimal ROI created by the test, and practical limitations in available analytical methods to interpret the resulting data.

Based on the limited information on hydraulic characteristics of the UMCf and the questionable results of the previous testing, additional aquifer tests in the UMCf were conducted as part of recent groundwater investigations in the Montrose Site area (Appendix B). Two short-term

aquifer tests were conducted at UMCf monitor wells CP-01 and DPT-1 (Appendix B). The test at monitor well DPT-1 included an observation well constructed near the pumping well and both tests included the use of alluvial aquifer monitor wells as observations wells. The objective of the aquifer tests was to obtain field data that could be used to estimate the hydraulic characteristics of the UMCf at the Site and to evaluate the potential hydraulic connection between the alluvial aquifer and the UMCf.

The results of the aquifer testing indicated that an initial pressure response was observed in the alluvial aquifer wells at the beginning of each test; however, little to no water level response was discernable thereafter (Appendix B). The results indicate that hydraulic communication exists between the alluvial aquifer and the UMCf.

The hydraulic conductivity of the UMCf was estimated at approximately 0.05 ft/d based on these aquifer tests (Appendix B). Although similar limitations exist in these aquifer tests as described above for the previous step testing (short duration and limited pumping rates), the estimates from these tests are more in line with the hydraulic conductivity that would be expected based on the UMCf lithology. In addition, the results from the analysis of the observation well monitored during the testing at DPT-1 are more reliable since the response in this well was not affected by well loss and represents actual aquifer response. Due to the significantly lower hydraulic conductivity of the UMCf, the transfer of groundwater between the alluvial aquifer and the UMCf is limited. This information further corroborates the conceptual understanding that the UMCf exhibits hydraulic properties of an aquitard beneath alluvial aquifer (Appendix B).

3.5.4 Upper Muddy Creek Formation Coarse-Grained Deposits

The deepest groundwater sub-unit investigated to date in the CSM study area is the UMCc. This sub-unit was previously referred to as the third water-bearing zone in the CSM study area. This sub-unit is referred to as the coarse-grained facies of the Muddy Creek aquifer at nearby sites (ENSR, 2005). Hydrogeologic data for the UMCc at the Site are limited. Until September 2004, the UMCc had only been evaluated by Tronox (ENSR, 2005). Tronox has drilled and completed seven UMCc (coarse-grained facies Muddy Creek) monitor wells to the east and northeast of the CSM study area (ENSR, 2005). Montrose drilled, installed, and sampled an UMCc monitor well at the Site in September 2004 (ET, 2005). The monitor well (MW-08) was

drilled and constructed as part of the Expedited Investigation to develop data on groundwater quality in the UMCc. A complete summary of the drilling, construction, and groundwater sampling monitor well MW-08 was prepared (ET, 2005).

A review of lithologic logs indicates that the UMCc is generally composed of well-graded sand and clayey sand at depths ranging from approximately 275 to 300 feet bgs (ET, 2005). Based on a review of lithologic logs of the seven Tronox monitor wells, UMCc appears to extend from beneath the Site north and east to the Tronox property.

3.5.4.1 Groundwater Movement and Water Levels

As indicated above, eight UMCc monitor wells are present in the CSM study area (Figure 3-6). The monitor wells are completed at varying depths within the UMCc and are located over a limited area. Although a detailed groundwater level contour map cannot be constructed with the present set of wells, examination of groundwater level data measured as part of Site-wide quarterly monitoring suggest that the movement of groundwater in the UMCc is from south to north, similar to that of the alluvial aquifer and UMCf (Figure 3-24).

Groundwater occurs in the UMCc under confined conditions. Groundwater levels in monitor wells completed in the UMCc rise to levels significantly higher than the top of the UMCc and in some localities rise above land surface. Depths to groundwater measured in UMCc wells typically range from approximately 45 feet bgs in the southern portion of the Site area to approximately 22 feet above land surface in the area of the GWTS (Table 3-3).

Groundwater elevations measured in UMCc monitor wells are typically 50 feet higher than groundwater elevations measured at nearby alluvial aquifer monitor wells (Table 3-3). Groundwater elevations measured in UMCc are approximately 30 feet higher than groundwater elevations measured at nearby UMCf monitor wells (Table 3-3). These data indicate that there is an upward vertical groundwater gradient between the UMCc and the overlying UMCf and alluvial aquifer. These data also indicate that the finer-grained sediments of the UMCf act as a confining unit (or aquitard) above the UMCc.

Water levels in UMCc monitor wells fluctuate slightly in the Site area. Based on water level data collected from November 2006 to July 2007, changes in water levels generally vary within one foot on a quarterly basis (Table 3-3).

3.6 <u>ECOLOGY</u>

In general, natural habitats do not exist at the Site given the developed and industrial and manufacturing operations of the property. Based on discussions with NDEP in a meeting on May 23, 2007, ecology is limited to the downgradient area (Section 7.0) (NDEP, 2007b).

4.0 NATURE AND EXTENT OF SITE-RELATED CHEMICALS

This section summarizes the nature and extent of SRCs in air, soil vapor, soil, and groundwater at the Site. Validated data obtained from recent and limited historical Site investigations were used to delineate the distribution of SRCs in the media identified above.   The database developed by the Companies to manage these data was provided to NDEP on July 12, 2007. The following types of tables and figures were prepared for Section 4.0 to support the evaluation of the distribution of representative SRCs in soil and groundwater:

- Prevalence Tables – the frequency of detection, minimum and maximum detected concentration, and exceedances of preliminary Site screening levels were summarized for SRCs in soil and groundwater.

- Soil Concentration Maps – the concentrations of representative SRCs in vadose zone soil were illustrated on maps and summarized in tables included on the large-format figures.

- Groundwater Concentration Contour Maps – the concentrations of representative SRCs in the alluvial aquifer were contoured within the CSM study area.

- Groundwater Post Map – the concentrations of representative SRCs in the UMCf were summarized on one post map.

- Sample Location Maps – maps showing the location of the soil vapor sampling locations and soil borings to support the evaluation of SRCs in soil vapor and saturated soil were prepared.

In addition, the following tables and figures were prepared to support the evaluation and are included in the appendices:

- Chemical Cross-Sections - cross-sections depicting the vertical distribution of representative SRCs were prepared for the former Montrose and Stauffer facility areas. The chemical cross-sections are included in Appendix D.

- Bubble Maps – concentration bubble maps for SRCs detected in soil above preliminary Site screening levels that are not evaluated in Section 4.0 are included in Appendix D. Concentration bubble maps for SRCs detected in groundwater above preliminary Site screening levels that are not evaluated in Section 4.0 are included in Appendix E.

- Summary Tables – summary tables of all SRC concentration data considered in the CSM for soil and groundwater are included on compact disc.

4.1 BACKGROUND OCCURRENCE OF SITE-RELATED CHEMICALS IN SOIL

The primary SRC groups that occur in background soil are metals and inorganic compounds.

A joint background soil study was performed by Timet and BRC to collect and evaluate data that were considered representative of background conditions at the BMI Complex and Common Areas (Timet, 2007a). The primary objective of this study was to develop a representative background soil data set that could be used to evaluate whether concentrations of SRCs detected in Site soil samples statistically exceeded background concentrations (Timet, 2007a). During the study, background samples were collected from soil up to a depth of 10 feet bgs, and were analyzed for metals, anions, and radionuclides. Background soil samples were not collected from depths greater than 10 feet bgs or in the Muddy Creek Formation.

Datasets used in the background analysis met data usability criteria (Timet, 2007a). The data analysis plots contain distributional plots, box-and-whisker plots, and individual result plots for each SRC. The statistical analysis that is used to support conclusions regarding exceedances of background includes both the parametric ANOVA and the non-parametric Kruskal-Wallace test. ANOVA assesses differences in mean concentrations among groups, and the Kruskal-Wallace model looks for differences in the sum of the ranks among groups. Nondetect results were replaced with half the detection limit (the Method Detection Limit was used for detection status) in the ANOVA model, and Gehan ranking was used to accommodate nondetects in the Kruskal-Wallace model.

Arsenic is the only metal detected in site soil at concentrations above the EPA Region IX Industrial Preliminary Remediation Goal (PRG) for soil of 1.59 mg/kg. Based on the background soil study cited above, a background concentration of 7.2 mg/kg was established for arsenic. This value represents the maximum concentration of arsenic detected as part of the study. The concentration of arsenic in Site soil relative this background concentration is discussed in Section 4.3.20.

4.2 EVALUATION OF SELECTED SITE-RELATED CHEMICALS IN AIR

This section summarizes the results of two independent evaluations of the potential presence of SRCs in air at the Site.

4.2.1 Pioneer Facility Study

The Center for Toxicology and Environmental Health, LLC (CTEH) performed a preliminary study of the ambient air at the Pioneer Facility (now owned by Olin) in August, 2002. The primary objective of the study was to determine if odors reported by workers at the Site were the result of chemicals historically used in certain areas of the site. In particular, the air study targeted areas on or near the former Stauffer and Montrose facilities (Figure 4-1). The results of the study were published in CTEH (2002). This following text presents a summary of the results of the study based on this report.

CTEH identified specific compounds to be reviewed as part of the study. They were selected based on results of past site investigations, history of use, and their potential to produce odors. The compounds evaluated were isomers of BHC, thiophenol, phosmet, carbophenothion, and VOCs. The areas of the plant considered for air monitoring were:

- The Former Lindane Plant including Warehouse, and Piles
- The Former ACD Site (Trithion/Imidan, Parachlorothiophenol/Thiophenol processes)
- Former Montrose Plant Site

Pioneer also asked CTEH to collect samples for airborne dust that deposits on vehicles and other surfaces at the plant and analyze these samples for metals. Due to their nonvolatile nature, metals were not considered an odor concern. CTEH selected the following list of metals for evaluation: arsenic, barium, cadmium, chromium, lead, magnesium, mercury, manganese, selenium, and silver.

CTEH collected integrated air samples at a total of 13 stations to determine the ambient concentrations of the selected compounds. The samples were collected using air sampling apparatus placed at or near breathing zone height (5 feet above ground surface) wherever possible. In some instances, CTEH collected samples at lower heights due to limitations

regarding handling of the sampling apparatus. The stations were located and sampled as follows:

Sample Stations	Locations	Sample height	Duration	Analysis
SS01 to SS03 (three sites)	Former Lindane Stockpile Area, Caustic loading shack	2.5 – 15 feet	individual integrated 24-hour samples over a 7 day period	BHC isomers (alpha-, delta-, and gamma BHC)
SS04	Pioneer Main Office	5.75 feet	one integrated sample over a 7 day period	Trace metals
SS05 to SS08 (four sites)	Former Lindane Stockpile area	2.5 – 5.5 feet	One integrated sample over a 24 hour period	thiophenol, phosmet and carbophenothion
SS09 to SS13 (five sites)	Former Montrose Plant Site	3.5 – 5.75	One integrated sample over a 24 hour period	Total VOCs

In addition to the integrated air samplers, CTEH performed personal air sampling for BHC isomers on two contract employees working outdoors moving railcars through the former lindane stockpile areas in and around the Stauffer Former Lindane Plant and Storage areas. These samples were collected after 175 minutes of sampling and were analyzed for BHC isomers only.

4.2.1.1   Former Lindane Stockpile Area, Caustic Loading Shack

Laboratory analysis of the air samples indicated that low concentrations of alpha-, delta-, and gamma-BHC existed in air at the former Lindane stockpile area (near former BHC Cake Piles 1 and 2) and caustic loading shack.

The detected concentrations of BHC isomers were as follows:

Sample Location	Range of Concentrations for 7 individual 24-hour integrated samples, in milligrams per cubic meter		
	alpha-BHC	delta-BHC	gamma-BHC (Lindane)
SS-01	0.0002 – 0.0010	0.00006 – 0.00010	<0.00001 – 0.00007
SS-02	0.00002 – 0.00007	<0.00001 – 0.00004	<0.00001 – 0.000001
SS-03	0.0001 – 0.0010	0.00003 – 0.00008	<0.00001 – 0.000002

Alpha- and delta-BHC were each also detected at a concentration of 0.0001 milligrams per cubic meter in samples collected from the personal air samplers worn by two workers, as follows:

Sample Location	Range of Concentrations for integrated 175 minute samples, in milligrams per cubic meter		
	alpha-BHC	delta -BHC	gamma-BHC (Lindane)
CANAC Worker	<0.00006	0.00006	<0.00006
CANAC Worker	0.0001	0.0001	<0.00006

The concentrations of gamma-BHC detected in both the sample locations and personal samples were well below the Occupational Safety and Health Administration (OSHA) exposure limit of 0.5 milligrams per cubic meter for gamma-BHC (lindane). According to CTEH, OSHA had not established exposure limits for alpha- or delta-BHC.

CTEH indicated that although there is no human information to indicate that alpha- and gamma-BHC are carcinogenic in humans, EPA treats these chemicals as if they are carcinogenic in humans because they cause cancer in laboratory animals. CTEH used the following formula to calculate Theoretical Lifetime Cancer Risk for the BHC isomers:

Theoretical Lifetime Cancer Risk = Air concentration x URF x 250/365 days per year x 25/70 years

Where:
- Air concentration – the concentration of the BHC isomer in air in milligrams per cubic meter;

- URF – Unit Risk Factor in cubic meters per milligram for individual isomer (alpha-BHC – 1.8, delta-BHC = not available, and gamma-BHC – 0.37);
- 250/365 days per year – EPA default occupational exposure frequency, and
- 25/70 years – EPA default occupational exposure duration.

Using the maximum detected concentrations of BHC isomers detected from the samplers, CTEH calculated the following theoretical lifetime cancer risks:

- alpha-BHC: 4E-04 for fixed sample locations and 4E-05 for personal samplers, and
- gamma-BHC: 6E-06 for fixed sample locations.

CTEH indicated that according to EPA policy acceptable lifetime cancer risks range between 1 in 1,000,000 and 1 in 10,000.

4.2.1.2   Pioneer Main Office

Low concentrations of the metals barium, manganese, and magnesium were detected in the air sample collected in front of the main office and were lower than the OSHA exposure limits. The detected concentrations and OSHA exposure limits were as follows:

Trace Meal	Concentrations in milligrams per cubic meter	
	Sample Result	OSHA Permissible Exposure Limit
arsenic	<0.00001*	0.01
barium	0.0001	0.5
cadmium	<0.00015*	0.002
chromium	<0.0001	1
lead	<0.00004*	0.05
magnesium	0.0008	0.5
manganese	0.0002	0.2
mercury	<0.000003	0.01
selenium	<0.0001	0.2
silver	<0.0001	0.01

* Original report was provided in micrograms per cubic meter

4.2.1.3 Former Lindane Stockpile Area

There were no detects of thiophenol, phosmet, or carbophenothion in the air samples collected at the Former Lindane Stockpile Area.

4.2.1.4 Former Montrose Plant Site

There were no detects of VOCs in the air samples collected at the Montrose Former Plant Site.

4.2.1.5   Conclusions

CTEH noted in its conclusions that the air sampling program conducted was preliminary in nature and represented a relatively short time period. As such, the results may not be representative of exposure conditions existing at other times of the year, existing as the result of changed site conditions, or due to other site activities.

A risk assessment workplan was recently submitted for Stauffer (Integral, 2008) that includes an evaluation of exposure to windblown particulates, including the SRC of asbestos. A tiered modeling approach is proposed to evaluate windborne particulates generated by wind erosion and construction activities.

4.2.2 Montrose Facility Study

An evaluation has also been performed to assess whether process air emissions from the former Montrose chemical manufacturing processes could have resulted in deposition of SRCs in offsite soils located near the Site (Earth Tech Inc., 2003). The report prepared for this study is included in Appendix F. This study evaluated potential air emissions from the following Montrose LOU items:

- Study Item 7 – Chlorobenzene and polychlorinated benzene manufacturing processes;
- Study Item 8 – Chloral (trichlorobenzene) manufacturing process;

- Study Item 9 – Dichlorobenzil manufacturing process;

- Study Item 10 – Synthetic hydrochloric acid manufacturing process;

- Study Item 11 – Ethyl chloride (1,2-dichloroethane) manufacturing process, and

- Study Item 12 – Miscellaneous plant air emissions (cooling towers, refrigeration units, and disposal ponds).

Earth Tech (2003) began the investigation by reviewing Section 4.4 and Appendix B of the ECI Report (Secor, 1997). These sections of the ECI report summarize the results of a Secor air quality engineer's independent review of documents pertaining to the air emission study items. The engineer reviewed facility design documents, facility production records, raw material purchase records and historical wind pattern data for the site. Each emission source was characterized by Secor as either gas, vapor, or particulate (mist, fume, or dust) in order to address the likelihood that air emissions from the former Montrose site would have been depositional in nature.

Earth Tech considered the behavior of the various types of emissions and concluded the following:

- Because gases and vapors are molecularly dispersed, they are not subject to deposition by gravitational and inertial forces. Therefore, gases or vapors released from the former Montrose Plant site would have rapidly mixed with air and would have been widely dispersed (over hundreds of miles) by even the lightest winds.

- It is possible that once airborne, secondary chemical reactions may cause gases or vapors to form fine liquid or solid particulate matter (i.e., mists or fumes). However, Earth Tech indicated that it is well established that these processes form particles less than 1 micron in diameter and particles of this size are not likely depositional in nature.

- Earth Tech indicated that the key to assessing the deposition potential for airborne solid or liquid particulate matter is the effective diameter of the individual particles and the resulting settling velocities that they exhibit.

- Particulate matter less than 10 microns in diameter exhibit very low settling velocities in still air (< 0.3 centimeters per second). Consequently, particles in this size range tend to form stable aerosols that behave similar to a gas and can remain in suspension over great distances (hundreds of miles). Earth Tech indicated that in the case of air stagnation or rain would it be theoretically possible for very small quantities of fine particulates to be deposited locally.

- Particulate matter larger than 10 microns in diameter (including coarse dust) exhibit significant still air setting velocities. Therefore, sustained wind speed and direction are key factors in assessing airborne transport of coarse particular matter. Earth Tech indicated that wind speeds less than 20 miles per hour (mph) cannot transport particulate matter greater than 10 microns in diameter.

Earth Tech reviewed historical wind speed and direction data for the years 1949 through 1978 from McCarran International Airport in Las Vegas (approximately eight miles northwest of the former Montrose site). Based on a wind rose diagram prepared using the data set (Appendix F), Earth Tech concluded that 52 percent of the time the dominant wind direction was southerly through westerly. Wind speeds were typically between 3 to 12 mph (57 percent of the time) and strong winds above 24 mph were infrequent, occurring only two percent of the time.

Earth Tech summarized operations at the six air emissions LOU study item areas and presented an assessment of the depositional potential for each emission source. The results of their assessment were as follows:

- Study Item 7 – Chlorobenzene and polychlorinated benzene manufacturing processes: releases of SRCs would have been non-continuous as gases and would not result in significant near-field deposition.

- Study Item 8 – Chloral (trichlorobenzene) manufacturing process: releases of SRCs would have been non-continuous as gases, vapors or fine mists (droplets less than one micron in diameter) and would not result in significant near-field deposition.

- Study Item 9 – Dichlorobenzil manufacturing process: releases of most SRCs would have been non-continuous as gases, vapors or fine mists (droplets less than one micron in diameter) and would not result in significant near-field deposition. However, DDT releases could be characterized as coarse dust sized particles (10 to greater than 1,000 microns) and deposition of these particles would likely occurred inside the property boundary. Additionally, dichlorobenzil may have been generated in sizes from 0.8 to 10 microns. Earth Tech indicated that this fine particulate matter if released would behave as a gas and would not result in significant near-field deposition.

- Study Item 10 – Synthetic hydrochloric acid manufacturing process: releases of SRCs would have been non-continuous as gasses and would not result in significant near-field deposition.

- Study Item 11 – Ethyl chloride (1,2-dichloroethane) manufacturing process: releases of SRCs would have been non-continuous as gasses and would not result in significant near-field deposition.

- Study Item 12 – Miscellaneous plant air emissions (cooling towers, refrigeration units, and disposal ponds). The releases of SRCs from the cooling tower and refrigeration unit were characterized as vapors and fumes that pose little potential for near field deposition. The waste disposal ponds during use were a potential sources of vapors which would not cause significant near-field deposition. When the ponds were dry, there was a potential for sediments to be picked up by strong winds. The loose soil or sediment that could have been present likely consisted of relatively large particles (10 to 3,000 microns) and would not have contributed significantly to off-site deposition. Earth Tech indicated that once the pond was capped in 1989, any particulate emissions from the pond sediments would have ceased.

The Earth Tech study concluded that the former Montrose air emission sources presented a negligible probability for offsite deposition of SRCs, as demonstrated by the following:

- With the exception of the synthetic hydrochloric acid and possibly soil vapors from the Closed Ponds Area, the air emission sources from the Montrose facility were eliminated by 1989.

- It is unlikely the potential sources identified above contributed to deposition of SRCs to the areas surrounding the Site. The historical air emissions from the potential source areas would have been in the form of gases, vapors, fine mists, fumes, and fine dusts. The study demonstrated that these emissions would mimic the air in which they were entrained, rapidly dilute, and would be transported hundreds of miles before they would settle out. As a result, soil sampling in the surrounding area would not provided useful information for further evaluation of process air emissions.

- The only air emission sources that were identified as depositional in nature were the DDT dust generated by the dichlorobenzil process and windblown contaminated soil and sediment form the Closed Ponds Area. However, these air emissions would have been infrequent and have only released small quantities of particulate matter. Furthermore, the particulate matter emitted would have consisted of course particles, which would not have been transported significant distances by even the strongest winds near the Site.

Earth Tech concluded that the former Montrose Plant air emission sources presented a negligible probability for deposition of site contaminants outside of the property boundary.

4.3 DISTRIBUTION OF SITE-RELATED CHEMICALS IN SOIL AND GROUNDWATER

This section summarizes the evaluation of the nature and extent of a representative subset of SRCs in soil and groundwater. Pursuant to a request from NDEP, the discussion of the nature and extent of representative SRCs in soil and groundwater in the CSM is organized by SRC. The combined list of SRCs includes 344 individual chemicals classified into the following chemical groups: aldehydes, asbestos (soil only), dioxins/furans, general chemicals, herbicides (groundwater only), indicator chemicals, inorganics, metals, organic acids, PCBs, pesticides, radionuclides (groundwater only), SVOCs, and VOCs (Earth Tech, 2006 and PES, 2006aa and 2006bb; Table 2-1).

4.3.1 Preliminary Site Screening Levels

Preliminary Site screening levels were developed based on selected regulatory screening levels in soil and groundwater. These preliminary Site screening levels were developed to provide a "frame of reference" to evaluate the relative magnitude of SRC concentrations in soil and groundwater at the Site. Because it is planned that Site-specific risk assessments will be completed to address the potential exposure to SRCs identified at the Site, the preliminary Site screening levels were developed for the sole purpose of assessing SRCs and/or SRC concentrations that may warrant further Site-specific study, including assessing data gaps.

The regulatory screening level used for soil was the EPA Region IX Industrial PRG (EPA, 2004). Industrial PRGs were selected because the current and future land uses at the Site are and will be industrial, respectively. Industrial PRGs are generic risk-based concentrations derived from standardized equations that are based on exposure assumptions and EPA toxicity data (EPA, 2004). They are generic standards estimated without Site-specific information and are not enforceable cleanup standards. They are considered by the EPA to be protective for humans (including sensitive groups), over a lifetime. However, Industrial PRGs are not always applicable to a particular site and do not address non-human health endpoints such as ecological impacts. Industrial PRGs exist for 126 different chemicals analyzed at the Site, 102 of which are SRCs.

Per the NDEP, EPA no longer updates the Region IX PRGs. Future work at the site will use the Region VI Medium Specific Screening Levels, for which the NDEP has indicated a preference (NDEP, 2008).

The EPA has also developed "Dilution Attenuation Factors" (DAFs) to reflect attenuation mechanisms applicable to the leaching of chemicals in soil that have the potential to impact underlying groundwater. DAFs are defined as "the ratio of contaminant concentration in soil leachate to the concentration in ground water at the receptor point" (EPA, 1996). DAFs are used by EPA in the derivation of leaching-based Soil Screening Levels (EPA, 1996). DAFs and leaching Soil Screening Levels are independent of land use scenarios (e.g., residential, commercial/industrial). Like the Industrial PRGs, DAFs are generic standards developed without Site-specific information and are not enforceable cleanup standards. Two DAF values have been established by the EPA: DAF-1 and DAF-20 (EPA, 2004). DAF-1 values represent soil concentrations where no dilution or attenuation occurs between soil and groundwater (i.e., "receptor well location"). DAF-20 concentrations are greater than the DAF-1 concentrations and account for dilution and attenuation of the chemical by natural processes during migration from soil to a groundwater receptor well location.

The DAFs have not been used as a screening criterion in this CSM to evaluate the risk to groundwater, however, the DAFs have been included in the tables for reference purposes. The DAFs were developed using a residential land use human exposure assumption and are based on non-Site-specific information. The current and future use of the Site will be industrial; therefore, the residential exposure assumption results in overly conservative DAFs. The fate and transport of SRCs at the Site are controlled by Site-specific physical and biochemical processes that likely differ from assumptions used to develop the DAFs. The Companies acknowledge that a subset of SRCs identified in soil at the Site have and may continue to impact underlying groundwater. Assessment of the degree to which existing soil contamination affects underlying groundwater quality will be performed by the Companies in future remedy evaluations assuming an industrial use scenario for the Site, and using Site-specific information to the greatest extent possible.

Although groundwater within the CSM study area is not used as a source of potable or drinking water, the regulatory screening levels for groundwater used in this CSM were the EPA Primary MCLs for drinking water. The MCLs were used solely as preliminary screening criteria in the

CSM; they are not considered cleanup goals. MCLs exist for 57 different chemicals analyzed at the Site (assuming all the PCB congeners are one chemical), 50 of which are SRCs.

4.3.2 <u>Evaluation of Site-Related Chemical Prevalence in Soil and Groundwater</u>

A prevalence evaluation was performed based on existing soil and groundwater analytical data to identify prevalent chemicals in the subsurface and chemicals that exceed the preliminary Site screening levels (Tables 4-1 through 4-6). The results of the prevalence evaluation are discussed in more detail in subsequent subsections of Section 4.0. The prevalence evaluation considered all analytical methods where a specific chemical was included. For example, 1,2-DCB is reported in both the EPA Method 8260B (VOCs) and 8270C (SVOCs) analyses, so the number of analyses reported in the tables are generally double that of other VOCs or SVOCs. The Site investigations performed at the Site included laboratory analyses for a number of chemicals that were not identified as SRCs for either the Montrose or Stauffer facilities. Overall, the combined SRCs for both former facilities comprised approximately 60 percent of the total chemicals analyzed.

<u>Site-Related Chemical Prevalence in Soil</u>

A total of 22 chemicals were detected in soil at concentrations that exceeded the Industrial PRG (Table 4-7). The SRCs that exceeded the Industrial PRGs are from the following chemical groups: VOCs, OCPs, SVOCs, dioxins/furans (2,3,7,8-tetrachlorodibenzo-p-Dioxin [TCDD] only), metals (arsenic only), and PCBs (aroclor-1254 only). VOCs and OCPs are the most prevalent chemicals detected in soil at concentrations exceeding preliminary Site screening levels, which is consistent with historical Site operations (Converse, 1993; Weston, 1993).

The distribution of SRCs in soil were further evaluated for surface soil, vadose zone soil, and saturated zone soil, as discussed in detail later in Section 4.0. Surface soil was assumed to comprise the interval from ground surface to two feet bgs. This interval is consistent with EPA protocols for non-invasive human health exposure assessment (EPA, 2002). Vadose zone soil was assumed to comprise the interval from the ground surface to the water table (approximately 45 to 50 feet bgs) at the Site. Saturated zone soil quality was characterized based on soil

samples collected below the water table in reconnaissance borings and borings associated with monitor wells in the alluvial aquifer and UMCf to a depth of approximately 170 feet bgs.

Site-Related Chemical Prevalence in Groundwater

A total of 38 chemicals were detected in groundwater at concentrations that exceeded the MCL (Table 4-7). The SRCs that exceeded the MCLs are from the following chemical groups: VOCs, OCPs (gamma-BHC only), SVOCs, dioxins/furans (2,3,7,8-TCDD only), metals, inorganics, and PCBs. VOCs are the most prevalent chemicals detected in the groundwater at concentrations exceeding preliminary Site screening levels, which is consistent with historical Site operations (Converse, 1993; Weston, 1993).

The distribution of SRCs in alluvial aquifer, UMCf, and UMCc groundwater were characterized based on analytical data from the period April 2005 to the present from the following sampling programs or events:

- Annual GWTS extraction well groundwater sampling;

- BRC CAMU area groundwater monitoring;

- Quarterly GWTS Consent Order groundwater monitoring;

- Quarterly GWTS transect well groundwater monitoring;

- Semi-annual Montrose Closed Ponds Area groundwater monitoring;

- 2004 Montrose limited groundwater sampling event;

- Stauffer and Montrose Phase I and II groundwater sampling for full list of SRCs;

- Downgradient area groundwater sampling event;

- Quarterly Site-Wide Groundwater Monitoring Program, and

- Grab groundwater samples collected as part of BRC and Montrose Site assessment activities (maps only, not included in summary statistics).

The April 2005 date was chosen to incorporate the comprehensive groundwater sampling event performed by BRC for their CAMU CSM. The summary statistics for groundwater prevalence are based on all available monitor and extraction well data (excluding grab samples) from April

2005 to the present. The most recent detected value was used from each well to prepare groundwater quality contour maps. However, in cases where laboratory method reporting limits (MRLs) were elevated for the most recent sampling event, previous data possessing lower MRLs were used in preparing the contour maps. In cases where laboratory MRLs were elevated for the VOC analyses by EPA Method 8260B for chlorobenzene and DCB s, the results from the EPA Method 8270C, which possessed lower MRLs, were used in preparing the contour maps.

4.3.3 <u>Representative Site-Related Chemicals in Soil and Groundwater</u>

Due to the extensive chemical analytical suite run on samples for the Supplemental Soil and Groundwater Investigations and the large number of chemicals detected at the Site, the analytical data were evaluated to develop a list of representative Site-Related Chemicals in soil and groundwater that could be used to illustrate the extent of Site Related Chemicals at the Site for this CSM. The method used to develop the list of representative chemicals is similar to EPA guidance for selection of Compounds of Concern (COCs) for risk assessment (EPA, 1989). Although the list of SRCs was reduced for the purpose of selecting representative SRCs for discussion purposes in this CSM, all of the SRCs will be evaluated further for inclusion in the risk assessment process. Based on the EPA guidance, chemicals were considered as representative SRCs if the chemical was detected above the MRL of the approved method of analysis and met the prevalence and relative toxicity criteria. These criteria included the following:

1. Prevalence – chemicals are considered representative if they were detected in one or more samples per twenty samples analyzed (5% or greater frequency), if less than 20 samples were analyzed for a SRC and the SRC was detected the chemical was considered but only retained if the maximum detected concentration was greater than or equal to 5 times the MCL or the published soil screening level of the PRG;

2. Relative toxicity – Only chemicals that have published MCLs for groundwater, published soil screening levels such as PRGs were selected because it is assumed that these chemicals are likely to contribute the bulk of the risk at the site and ultimately drive the selected remedy for the Site. Chemicals that were detected at concentrations greater than MCLS in groundwater samples or greater than preliminary screening levels (PRGs) in soil samples in at least 5% of samples analyzed were selected; alternatively, if the maximum detected concentration in any

sample was 5 times the MCL or published screening level the chemical was selected, and

3. Other prevalent chemicals known to have been used or disposed of at the Site that do not have preliminary screening levels to use as an indication of relative toxicity (organic acids, pesticides) or that do not have preliminary screening levels but are subject to other regulatory limits (Total Dissolved Solids) were also selected.

Based on these criteria, the chemicals that were detected at concentrations greater than their respective screening goals (soil industrial PRGs and groundwater MCLs) were evaluated to retain representative chemicals (Table 4-7 rev). Initially, the list of potential chemicals was evaluated based on criteria 1 and 2 above. This evaluation resulted in the selection of a total of 31 chemicals from 8 chemical groups as representative SRCs for the Site (Table 4-7 rev). Of the 31 chemicals, 16 exceeded the soil PRG and 25 chemicals exceeded the MCL for groundwater.

In addition to the 31 chemicals selected based on prevalence and relative toxicity, four additional chemicals were added based on criteria number 3. Carbophenothion (pesticide), bis(4-chlorophenyl) disulfide (SVOC), DMPT (Organic acid) and TDS were added to the list. Carbophenothion (pesticide), and bis(4-chlorophenyl) disulfide (SVOC) do not have soil or groundwater screening goals but were added because of their wide spread use. DMPT was added because of the State of Nevada Drinking Water Human Health Toxicity Criteria of 3,700 µg/l. TDS was added because of the State of Nevada limit of 1,900 mg/l limit for the Las Vegas Wash area. The following is a list of the chemical groups and chemicals selected as representative SRCs. Maps and tables depicting the extent of these chemicals have been prepared and are included among Figures 4-3 through 4-42, Appendix D and Appendix E.

- VOCs – benzene, chlorobenzene, 1,2-DCB, 1,4-DCB, chloroform, carbon tetrachloride, PCE, TCA, 1,2-DCA, methylene chloride, TCE, DBCP and Total Trihalomethanes (Total THM);

- Pesticides – BHC isomers (including alpha-BHC, beta-BHC, gamma-BHC), 4,4'-DDT, 4,4'-DDE, and carbophenothion;

- SVOCs – 1,2,4-TCB, bis(4-chlorophenyl) disulfide, hexachlorobenzene and bis(2-ethylhexyl) pthalate;

- Dioxins/Furans – 2,3,7,8-TCDD;

- PCBs – Arochlor 1254;

- Metals – arsenic, chromium, lead, thallium and uranium;

- Organic acids – DMPT, and

- General Chemicals – fluoride, nitrate/nitrite and TDS.

This list of chemicals, however, is still very large. In order to reduce the repetitive effort of discussing all 35 chemicals in detail in the text, the 35 chemicals were further evaluated to determine if some chemicals from each group had similar characteristics and, thus, are likely to have similar fate and transport characteristics. To evaluate the characteristics of each chemical a matrix was prepared to quickly compare chemicals relative properties (Table 4-8A). Each factor in the matrix was assigned a high or low value based on the range of values for each factor. The factors evaluated included:

- Prevalence based on the frequency of detections above the method reporting limit, if a chemical was detected in 10% or more of the samples analyzed it was assigned a high prevalence, less than 10% assigned a low prevalence;

- Relative Toxicity based on a combination of the industrial PRGs for soil samples and MCLs for groundwater samples and the frequency of detections above these screening levels. A chemical was given a high relative toxicity if it's PRG in soil was less than 10 mg/kg or it's MCL in groundwater was less than 10 ug/l. The chemical was also given a high relative toxicity if 10% or more of the samples had concentrations greater than their respective PRG or MCL.

In addition, once the chemicals were evaluated based on the prevalence and relative toxicity, the chemicals were evaluated based on their physicochemical properties including the following:

- Molecular Weight – high values were assigned to chemicals with molecular weights greater than 200 grams/mole,

- Density (Specific Gravity) – high values were assigned to chemicals with a density greater than 1 grams/cubic centimeter and low to chemicals with a density less than or equal to 1,

- Vapor Pressure – a vapor pressure greater than 0.01 mm Hg were considered high and less than or equal to 0.01 mm Hg were considered low,

- Henry's Law Constant – chemicals with a published Henry's Law Constant less than or equal to 0.0001 (E-04) cubic meters/mole were given a low value, those with a constant greater than E-04 were assigned a high value,

- Water Solubility – chemicals with a published water solubility value of less than or equal to 10,000 mg/l were considered to have low solubility and greater than 10,000 mg/l were considered to have high solubility, and

- Organic Carbon (log Koc) and Octanol Water (log Kow) partition coefficients – chemicals with partition coefficients of less than 3 were assigned a low value, greater than or equal to 3 a high value.

Based on review of Table 4-8A, the chemicals from each chemical group that were given high values for prevalence and relative toxicity were considered as potential representative SRC. If a chemical group had only one representative chemical it was automatically included as a representative chemical for discussion in the text. If two or more chemicals from the same chemical group had similar physicochemical properties, the more prevalent chemicals and the chemicals with the highest relative toxicity based on published PRGs/MCLs and number of samples that exceed them were selected for detailed discussion. The other chemicals were retained as supplemental SRCs and were not discussed in the text. However, maps and cross-sections that depict the distribution of all of the representative SRC and supplemental SRCs are provided in Appendices D and E.

In summary, the representative SRCs discussed in the text were selected based on their widespread historic use or disposal at the Site, prevalence, relative toxicity and represented the range of physicochemical properties. These chemicals were selected because they are typically the most prevalent detected in soil and groundwater samples at the Site, have the highest relative toxicity based on their industrial PRG or groundwater MCL. These chemicals were also selected because they provide a range of physicochemical characteristics of the chemicals detected at the site. For example, chemicals with high and low water solubility and high and low specific gravity were selected to be representative of potential DNAPL and LNAPL formers. In addition, certain chemicals were retained based on criteria number 4 as described previously. The chemical groups and representative SRCs selected for detailed discussion in this section of the CSM report include:

- VOCs - Benzene, Chlorobenzene, 1,2-DCB, 1,4-DCB, Chloroform, ,carbon tetrachloride and, PCE;

- SVOCs - 1,2,4-TCB and bis(4-chlorophenyl) disulfide;

- Pesticides - BHC isomers (including alpha-BHC, beta-BHC, gamma-BHC), 4,4'-DDT, 4,4'-DDE, and carbophenothion;

- Organic acids – DMPT;

- Metals – arsenic;

- PCBs – Arochlor 1254;

- Dioxins/Furans – 2,3,7,8-TCDD, and

- General Chemicals – TDS.

The following chemicals were selected as supplemental SRCs because they are less prevalent, considered to have lower relative toxicity based on lower maximum concentrations relative to screening levels or have similar physiochemical characteristics to the chemicals selected as representative SRCs (Table 4-8):

- VOCs – TCA, 1,2-DCA, methylene chloride, TCE, DBCP and Total Trihalomethanes (Total THM);

- SVOCs – hexachlorobenzene and bis(2-ethylhexyl) pthalate;

- Metals – chromium, lead, thallium and uranium, and

- General Chemicals – fluoride and nitrate/nitrite.

4.3.4 VOCs in Soil Vapor

The evaluation of SRCs in soil vapor was based on the results of the soil vapor survey performed in 2006 around the Montrose Closed Ponds Area to characterize the presence of VOCs (H+A, 2005b). Figure 4-2 shows the sampling locations from this soil vapor survey. Additional details on this soil vapor survey are included in Appendix B. Based on the result of the soil vapor survey, the following VOCs were detected in at least five percent of the vapor samples collected: 1,1-dichloropropene, 2-butanone, acetone, bromodichloromethane, carbon tetrachloride, chloroform, and toluene (Appendix D, Tables D-1 through D-8). Carbon

tetrachloride and chloroform were the most frequently detected VOCs in soil vapor and were detected at the highest concentrations.

4.3.5 Benzene in Soil and Groundwater

Benzene was used as a raw product in the former manufacturing processes at the Site. Benzene is a VOC that is lighter than water. In comparison with other representative SRCs, benzene is relatively soluble in water and relatively mobile in the subsurface (Table 4-8). The distribution of benzene in soil and groundwater is described below. Chemical cross-sections depicting the vertical distribution of benzene in the subsurface are included in Appendix D, Figures D-1A and D-1B.

4.3.5.1 Benzene in Surface Soil

Benzene was detected above laboratory MRLs in 37 of the 75 surface soil analyses (approximately 49 percent) (Table 4-1 and Figure 4-3). Benzene was detected at trace concentrations in surface soil over a large portion of the Site. Detectable benzene concentrations in surface soil ranged from 0.0005 to 2.1 mg/kg. The maximum benzene concentration was detected at a depth of 0.5 feet bgs from boring EC-10 located north of the BHC Cake Pile 3 and represents the sole exceedance of the benzene Industrial PRG of 1.41 mg/kg.

As further indicated on Figures 4-3 and 4-5, deeper soil samples collected from boring EC-10 and groundwater samples collected from groundwater monitor well GW-EC-10 indicate that benzene concentrations attenuate with depth at this location and do not impact groundwater. For example, benzene concentrations in soil decrease from 2.1 mg/kg at the surface to 0.0016 mg/kg at 40.5 feet bgs (just above the water table) and benzene was not detected at concentrations exceeding the MRL of 2.0 ug/l in groundwater samples collected from monitor well GW-EC-10.

4.3.5.2 Benzene in Vadose Zone Soil

Benzene was detected above laboratory MRLs in 186 of the 431 vadose zone soil analyses (approximately 43 percent) (Table 4-2 and Figure 4-3). Detectable benzene concentrations in vadose zone soil ranged from 0.00046 to 4,700 mg/kg. Benzene was detected in 63 samples at concentrations greater than the Industrial PRG of 1.41 mg/kg (approximately 15 percent of the total number of samples).

Benzene concentrations in the vadose zone were generally highest beneath the Montrose Former Plant Site. The maximum benzene concentration was 4,700 mg/kg detected at 15 feet bgs in soil boring FPS-13. In the Montrose Former Plant Site, the highest benzene concentrations were generally found between 15 and 20 feet bgs. An SVE system is currently operating in the northwest portion of the Montrose Former Plant Site to remove VOC-impacted vapor (including benzene) from the vadose zone to depth of approximately 42 feet bgs (Section 2.4.2).

Additional areas where benzene was detected above the Industrial PRG in vadose zone soil include:

- Montrose Former Tank Farm – benzene was detected in two soil samples in the central portion of the Montrose Former Tank Farm at concentrations as high as 29 mg/kg between the depths of 45 and 50 feet bgs.

- Stauffer Former ACD Plant – benzene was detected above the Industrial PRG in two soil borings (SB-EC-12 and SB-EC-13) in the western portion of the Stauffer Former ACD Plant at concentrations ranging from 20 to 280 mg/kg between the depths of 7.5 and 41.5 feet bgs.

- BHC Cake Pile 3 – as previous discussed, benzene was detected in soil boring EC-10 located immediately north of the BHC Cake Pile 3 at concentrations above the Industrial PRG to a depth of 7.5 feet bgs, but concentrations attenuate with depth.

- Former BHC Cake Pile 1, the Former Lindane Plant, and Montrose and Stauffer Former Benzene UST, CAPD Pond 3, northeast of CAPD Pond 3, and west of the Montrose Former Plant Site. Exceedances of the Industrial PRG in each of these areas are limited to soil samples collected below approximately 34 feet bgs (i.e. closer to the top of the saturated zone) and may be related to vapor phase partitioning of benzene in groundwater.

Benzene was not detected above the Industrial PRG in the Montrose Closed Ponds Area; the Former Leach Field and Phosphoric Acid Pond/Trenches, or the ACD Drum Burial Waste Management Area.

4.3.5.3 Benzene in Saturated Zone Soil

Benzene was detected above laboratory MRLs in 139 of the 166 saturated zone soil analyses (approximately 84 percent) (Table 4-3, Figure 4-4, and Appendix D, Table D-9). Detectable benzene concentrations in the saturated zone soil ranged from 0.00047 to 1,200 mg/kg. The maximum concentration of benzene in saturated zone soil was detected at a depth of 61 feet bgs in reconnaissance boring RB-03 located in the Montrose Former Plant Site.

4.3.5.4 Benzene in Groundwater

Alluvial Aquifer

The distribution of benzene in alluvial aquifer groundwater at the Site is shown on Figure 4-5. Benzene was detected above laboratory MRLs in 169 of the 330 groundwater analyses from the alluvial aquifer (approximately 51 percent) (Table 4-4). Detectable benzene concentrations in alluvial aquifer groundwater ranged from 0.38 to 700,000 ug/l. The maximum benzene concentration was detected in December 2006 in alluvial aquifer monitor well EC-07 near the Montrose Former Benzene Storage Tank. Benzene was detected in 152 groundwater samples at concentrations above the MCL for benzene of 5 ug/l (approximately 46 percent of the total number of samples).

Benzene was generally not detected in the alluvial aquifer upgradient of the former facilities with the exception of a single detection of benzene in monitor well H-11 at a concentration of 0.91 ug/l (Figure 4-5). Benzene was detected above the MCL in the alluvial aquifer over a broad area beneath former Site facilities, beneath the proposed BRC CAMU, and near the GWTS. The highest benzene concentrations are detected in the central portion of the Pioneer property. In general, benzene concentrations decrease from the former facilities in the southern portion of the onsite area to the GWTS, with the exception of the Slit Trench Area of the proposed BRC CAMU, where relatively elevated concentrations of benzene in the alluvial aquifer identified in

grab groundwater samples collected in April 2005 appear to represent a separate source of benzene to the alluvial aquifer.

The extent of benzene in the alluvial aquifer is well defined, with the exception of the eastern Pioneer property boundary, based on the extensive groundwater monitor well network associated with the Site. The uncertainty in the eastern extent of benzene in the alluvial aquifer represents a data gap, as identified in Section 9.0, which will be addressed during subsequent site characterization activities. Additionally, benzene was detected slightly above the MCL in alluvial aquifer monitor well AA-BW-13A, which is located along a dry wash that exists east of the Pioneer property that may have historically received storm water runoff from the former facilities. The downgradient extent of benzene in the alluvial aquifer in this area appears to be defined based on the results of the grab groundwater sample WDE-04, which did not contain benzene at concentrations at or above the MRL of 5 ug/l.

With the exception of monitor wells H-10A and H-49A, benzene was not detected above the MCL in alluvial aquifer groundwater downgradient (north) of Warm Springs Road to the area near Las Vegas Wash. The downgradient extent of benzene in the alluvial aquifer downgradient of monitor wells H-10A and H-49A was defined by the laboratory analytical results of groundwater samples collected from H-58A and PC-040, respectively, which did not contain benzene at concentrations at or above the MRL of 2.0 ug/l. Based on the substantial reduction of benzene concentrations downgradient of the GWTS, the GWTS appears to be effective at controlling the migration of benzene in the alluvial aquifer groundwater (Figure 4-5).

Fine-Grained Upper Muddy Creek Formation

Benzene was detected above laboratory MRLs in 25 of the 31 groundwater samples collected from the UMCf (approximately 81 percent) (Figure 4-6A and Table 4-5). Detectable benzene concentrations in UMCf groundwater ranged from 68 to 300,000 ug/l. The maximum benzene concentration was detected in October 2006 in UMCf monitor well MC-MW-09 (screened from 90 to 120 feet bgs) located in the Montrose Former Plant Site. Benzene was detected in 25 groundwater samples collected from UMCf monitor wells above the MCL (approximately 81 percent of the total number of samples). The extent of benzene in UMCf groundwater has not been fully defined. The uncertainty in the extent of benzene within the UMCf at the Site

represents a data gap and additional characterization activities are ongoing to further delineate the extent of impacted groundwater in the UMCf, as further described in Section 9.0.

Coarse-Grained Upper Muddy Creek Formation

Benzene was detected above laboratory MRLs in two of the 16 groundwater samples collected from the UMCc (approximately 13 percent) (Table 4-6 and Figure 4-6B). Benzene was detected in two groundwater samples collected from UMCc monitor wells at concentrations of 0.76 and 140 ug/l. Benzene was detected at a concentration of 140 ug/l in a groundwater sample collected from monitor well MW-08 in October 2006. The benzene concentration is anomalous. Monitor well MW-08 is located approximately 900 feet north of the Montrose Former Plant Site and represents the sole exceedance of the MCL for benzene for groundwater samples collected from the UMCc. Benzene has not been detected in MW-08 since October 2006. The lack of benzene detections after October 2006 suggests that the detections may have been the result of incomplete decontamination of sampling equipment during the October 2006 sampling event. The apparently anomalous detection of benzene at MW-08 will continue to be assessed through future groundwater monitoring of MW-08.

4.3.6 Chlorobenzene in Soil and Groundwater

Chlorobenzene was produced at the Site from 1947 to 1983. Chlorobenzene is a VOC that is heavier than water. In comparison with other the representative SRCs, chlorobenzene is moderately soluble in water and relatively mobile in the subsurface (Table 4-8). The distribution of chlorobenzene in soil and groundwater is described below. Chemical cross-sections depicting the vertical distribution of chlorobenzene in the subsurface are included in Appendix D, Figures D-2A and D-2B.

4.3.6.1 Chlorobenzene in Surface Soil

Chlorobenzene was detected above laboratory MRLs in 38 of the 75 surface soil analyses (approximately 51 percent) (Table 4-1 and Figure 4-7). Detectable chlorobenzene concentrations in surface soil ranged from 0.00061 to 25 mg/kg. The maximum chlorobenzene

concentration detected in surface soil was at a depth of 2 feet bgs in soil borings FPS-07 and FPS-08 located in the Montrose Former Plant Site. Chlorobenzene was not detected in surface soil at concentrations above the Industrial PRG of 530 mg/kg.

4.3.6.2 Chlorobenzene in Vadose Zone Soil

Chlorobenzene was detected above laboratory MRLs in 220 of the 431 vadose zone soil analyses (approximately 51 percent) (Table 4-2 and Figure 4-7). Detectable chlorobenzene concentrations in vadose zone soil ranged from 0.00054 to 42,000 mg/kg. Chlorobenzene was detected in 42 samples at concentrations greater than the Industrial PRG of 530 mg/kg (approximately 10 percent of the total number of samples).

Chlorobenzene concentrations in the vadose zone were generally highest beneath the Montrose Former Plant Site. The maximum chlorobenzene concentration detected in vadose zone soil was from soil boring FPS-13 in the Montrose Former Plant Site. In the Montrose Former Plant Site, the highest chlorobenzene concentrations were typically found at depths from 10 to 30 feet bgs. An SVE system is currently operating in the Montrose Former Plant Site to remove VOC-impacted vapor (including chlorobenzene) from vadose zone soil to a depth of approximately 42 feet bgs.

Additional areas where chlorobenzene was detected above the Industrial PRG in vadose zone soil include:

- Montrose Former Tank Farm – chlorobenzene was detected in two borings (FTF-07D and FTF-09D) at concentrations ranging from 630 to 18,000 mg/kg.

- Stauffer Former ACD Plant – chlorobenzene was detected in one isolated soil boring (SB-EC-12) at concentrations of 1,500 to 1,300 mg/kg at depths of 7.5 and 26 feet bgs, respectively.

Chlorobenzene was not detected above the Industrial PRG in the Montrose Closed Ponds Area, Montrose Former Benzene Storage Tank Area, or any former Stauffer facility other than the Former ACD Plant (Figure 4-7).

4.3.6.3 Chlorobenzene in Saturated Zone Soil

Chlorobenzene was detected above laboratory MRLs in 110 of the 166 saturated zone soil analyses (approximately 66 percent) (Table 4-3, Figure 4-4, and Appendix D, Table D-10). Detectable chlorobenzene concentrations in the saturated zone soil ranged from 0.00059 to 18,000 mg/kg. The maximum concentration of chlorobenzene in saturated zone soil was detected at a depth of 61 feet bgs in reconnaissance boring RB-03 located in the Montrose Former Plant Site.

4.3.6.4 Chlorobenzene in Groundwater

Alluvial Aquifer

The distribution of chlorobenzene in alluvial aquifer groundwater at the Site is shown on Figure 4-8. Chlorobenzene was detected above laboratory MRLs in 188 of the 330 groundwater analyses from the alluvial aquifer (approximately 57 percent) (Table 4-4).   Detectable chlorobenzene concentrations in alluvial aquifer groundwater ranged from 0.37 to 170,000 ug/l. The maximum chlorobenzene concentrations were detected in October and December 2006 in alluvial aquifer monitor wells B-03 and B-01, respectively.   B-03 and B-01 are located approximately 400 and 200 feet north of the Montrose Former Plant Site, respectively. The maximum concentration is greater than the MCL for chlorobenzene of 100 ug/l. Chlorobenzene was detected in 140 analyses above the MCL (approximately 42 percent of the total number of samples).

Chlorobenzene was generally not detected in the alluvial aquifer upgradient of the former operational areas (Figure 4-8). Chlorobenzene was detected above the MCL in the alluvial aquifer over large portions of the former operational areas, beneath the proposed BRC CAMU, and near the GWTS. The highest chlorobenzene concentrations are detected in an area extending from north of the Montrose Closed Ponds Area to north of the Montrose Former Plant Site. In general, chlorobenzene concentrations decrease from the operational areas in the southern portion of the onsite area to the GWTS, with the exception of the western Slit Trench Area, where chlorobenzene concentrations in the alluvial aquifer as high as 32,000 ug/l were detected in groundwater grab samples collected in April 2005.

The extent of chlorobenzene in the alluvial aquifer is well defined, with the exception of the area along the eastern Pioneer property boundary, based on the extensive groundwater monitoring network associated with the Site. The uncertainty in the eastern extent of chlorobenzene in the alluvial aquifer represents a data gap, as identified in Section 9.0, which will be addressed during subsequent site characterization activities.

With the exception of monitor wells H-10A, MC-49, and MC-50, chlorobenzene is not detected above the MCL in alluvial aquifer groundwater downgradient of the GWTS. Chlorobenzene concentrations in alluvial aquifer groundwater are less than laboratory MRLs in most of the monitor wells downgradient of the GWTS, especially those in the northern portion of the downgradient area. Based on the substantial reduction of chlorobenzene concentrations across the GWTS area, the GWTS appears to be effective at controlling the migration of chlorobenzene in the alluvial aquifer groundwater (Figure 4-8).

Fine-Grained Upper Muddy Creek Formation

Chlorobenzene was detected above laboratory MRLs in 27 of the 31 groundwater samples from the UMCf (approximately 87 percent) (Table 4-5 and Figure 4-6A). Detectable chlorobenzene concentrations in UMCf groundwater ranged from 3.9 to 320,000 ug/l. The maximum chlorobenzene concentration was detected in December 2006 in UMCf monitor well MC-MW-12 (screened from 100 to 120 feet bgs) located approximately 800 feet northeast of the Montrose Former Plant Site. The maximum concentration is greater than the MCL. Chlorobenzene was detected in 23 analyses above the MCL (approximately 74 percent of the total number of samples). The extent of chlorobenzene in the UMCf groundwater is not fully defined. The uncertainty in the extent of chlorobenzene within the UMCf represents a data gap and additional characterization activities are ongoing to further delineate the extent of impacted groundwater within the UMCf, as further discussed in Section 9.0.

Coarse-Grained Upper Muddy Creek Formation

Chlorobenzene was detected above laboratory MRLs in six of the 16 groundwater samples from the UMCc (approximately 38 percent) (Table 4-6 and Figure 4-6B). Detectable chlorobenzene concentrations in UMCc groundwater ranged from 0.39 to 150 ug/l. The maximum chlorobenzene concentration was detected in October 2006 in UMCc monitor well MW-08, and represents the sole detection above the MCL in the UMCc. Chlorobenzene has not been detected above laboratory MRLs in MW-08 since October 2006. The lack of chlorobenzene detections after October 2006 suggests that the lone detection may have been the result of incomplete decontamination of sampling equipment during the October 2006 sampling event. The apparently anomalous detection of chlorobenzene at MW-08 will continue to be assessed through future groundwater monitoring of MW-08.

Low concentrations of chlorobenzene ranging from 0.56 to 2.2 ug/l have been detected in Tronox UMCc monitor wells TR-01, TR-03, TR-05, and TR-11 over the period December 2006 to April 2007.

4.3.7 1,2-Dichlorobenzene in Soil and Groundwater

1,2-DCB was produced at the Site from 1947 to 1983. 1,2-DCB is a VOC that is heavier than water. In comparison with other representative SRCs, 1,2-DCB has low to moderate solubility in water and is moderately mobile in the subsurface (Table 4-8). The distribution of 1,2-DCB in soil and groundwater is described below. Chemical cross-sections depicting the vertical distribution of 1,2-DCB in the subsurface are included in Appendix D, Figures D-3A and D-3B.

4.3.7.1 1,2-Dichlorobenzene in Surface Soil

1,2-DCB was detected above laboratory MRLs in 41 of the 112 surface soil samples (approximately 37 percent) (Table 4-1 and Figure 4-9). Detectable 1,2-DCB concentrations in surface soil ranged from 0.0012 to 40 mg/kg. The maximum 1,2-DCB concentration detected in surface soil was from boring FPS-06 located in the Montrose Former Plant Site. 1,2-DCB was not detected in surface soil at concentrations above the Industrial PRG of 600 mg/kg.

4.3.7.2 1,2-Dichlorobenzene in Vadose Zone Soil

1,2-DCB was detected above laboratory MRLs in 287 of the 760 vadose zone soil samples (approximately 38 percent) (Table 4-2 and Figure 4-9). Detectable 1,2-DCB concentrations in vadose zone soil ranged from 0.00070 to 9,600 mg/kg. 1,2-DCB was detected in 28 samples at concentrations greater than the Industrial PRG (approximately four percent of the total number of samples).

1,2-DCB concentrations in the vadose zone were generally highest beneath the Montrose Former Plant Site. The maximum 1,2-DCB concentration of 9,600 mg/kg detected in vadose zone soil was at 15 feet bgs in boring FPS-13 in the Montrose Former Plant Site. Concentrations of 1,2-DCB generally increased with depth from the surface to approximately 30 feet bgs and decreased with depth below approximately 30 feet bgs. An SVE system is currently operating in the Montrose Former Plant Site to remove VOC-impacted vapor from vadose zone soil to a depth of approximately 42 feet bgs.

1,2-DCB was also detected above the Industrial PRG in vadose zone soil in an isolated soil boring in the central portion of the Montrose Former Tank Farm at concentrations as high as 4,700 mg/kg (Figure 4-9). 1,2-DCB was not detected above the Industrial PRG in vadose zone soil beneath the Montrose Closed Ponds Area or the former Stauffer facilities (Figure 4-9).

4.3.7.3 1,2-Dichlorobenzene in Saturated Zone Soil

1,2-DCB was detected above laboratory MRLs in 149 of the 313 saturated zone soil analyses (approximately 48 percent) (Table 4-3, Figure 4-4, and Table D-11). Detectable 1,2-DCB concentrations in the saturated zone soil ranged from 0.0012 to 6,100 mg/kg. The maximum concentration of 1,2-DCB in saturated zone soil was detected at a depth of 61 feet bgs in reconnaissance boring RB-03 located in the Montrose Former Plant Site.

4.3.7.4   1,2-Dichlorobenzene in Groundwater

Alluvial Aquifer

The distribution of 1,2-DCB in alluvial aquifer groundwater at the Site is shown on Figure 4-10. 1,2-DCB was detected above laboratory MRLs in 266 of the 502 groundwater samples from the alluvial aquifer (approximately 53 percent) (Table 4-4). Detectable 1,2-DCB concentrations in alluvial aquifer groundwater ranged from 0.54 to 36,000 ug/l. The maximum 1,2-DCB concentrations were detected in October 2005 in alluvial aquifer monitor well MW-03 located immediately north of the Montrose Closed Pond 5. The maximum concentration is greater than the MCL for 1,2-DCB of 600 ug/l. 1,2-DCB was detected in 64 samples above the MCL (approximately 13 percent of the total number of samples).

1,2-DCB was not detected in the alluvial aquifer upgradient of the former operational areas (Figure 4-10). 1,2-DCB was detected above the MCL in the alluvial aquifer beneath and downgradient of the Montrose Former Plant Site and Closed Ponds Area; in a localized area near the northern boundary of the Pioneer property; and in extraction wells F and G in the GWTS. In general, 1,2-DCB concentrations decrease from the operational areas in the southern portion of the onsite area to the GWTS.

The extent of 1,2-DCB in the alluvial aquifer is well defined, with the exception of a small area east of the Montrose Former Plant Site, based on the extensive groundwater monitor well network associated with the Site. The uncertainty in the eastern extent of 1,2-DCB in the alluvial aquifer represents a data gap, as identified in Section 9.0, which will be addressed during subsequent site characterization activities.

1,2-DCB was not detected above the MCL in alluvial aquifer groundwater downgradient on the GWTS. In the downgradient area, detectable concentrations of 1,2-DCB are limited to the area south of monitor well MW-K1. 1,2-DCB is not detected above laboratory MRLs in the northern portion of the downgradient area near Las Vegas Wash. Based on the substantial reduction of 1,2-DCB concentrations across the GWTS area, the GWTS appears to be effective at controlling the migration of 1,2-DCB in the alluvial aquifer groundwater (Figure 4-10).

Fine-Grained Upper Muddy Creek Formation

1,2-DCB was detected above laboratory MRLs in 43 of the 57 groundwater samples from the UMCf (approximately 75 percent) (Table 4-5 and Figure 4-6A). Detectable 1,2-DCB concentrations in UMCf groundwater ranged from 0.92 to 14,000 ug/l. The maximum 1,2-DCB concentration was detected in December 2006 in UMCf monitor well MC-MW-12. The maximum concentration is greater than the MCL. 1,2-DCB was detected in 27 samples above the MCL (approximately 47 percent of the total number of samples). The extent of 1,2-DCB in UMCf groundwater is not fully defined. The uncertainty in the extent of 1,2-DCB within the UMCf at the Site represents a data gap and additional characterization activities are ongoing to further delineate the extent of impacted groundwater in the UMCf, as further discussed in Section 9.0.

Coarse-Grained Upper Muddy Creek Formation

1,2-DCB was detected above laboratory MRLs in one of the 32 groundwater samples from the UMCc (approximately three percent) (Table 4-6 and Figure 4-6B). The 1,2-DCB concentration in this sample was 1.9 ug/l from monitor well MW-08 in October 2006. This concentration is less than the MCL for 1,2-DCB. 1,2-DCB has not been detected in MW-08 since October 2006. As previously discussed, this anomalous detection may be the result of incomplete decontamination during sampling and the presence of 1,2-DCB in UMCc will continue to be assessed through future groundwater monitoring of MW-08.

4.3.8 1,4-Dichlorobenzene in Soil and Groundwater

1,4-DCB was produced at the Site from 1947 to 1983. 1,4-DCB is a VOC that is heavier than water. In comparison with other representative SRCs, 1,4-DCB has low to moderate solubility in water and is moderately mobile in the subsurface (Table 4-8). The distribution of 1,4-DCB in soil and groundwater is described below. Chemical cross-sections depicting the vertical distribution of 1,4-DCB in the subsurface are included in Appendix D, Figures D-4A and D-4B.

4.3.8.1 1,4-Dichlorobenzene in Surface Soil

1,4-DCB was detected above laboratory MRLs in 42 of the 112 surface soil samples (approximately 38 percent) (Table 4-1 and Figure 4-11). Detectable 1,4-DCB concentrations in surface soil ranged from 0.0013 to 59 mg/kg. The maximum 1,4-DCB concentration detected in surface soil was from boring FPS-06 located in the Montrose Former Plant Site. The maximum concentration is greater than the 1,4-DCB Industrial PRG of 7.87 mg/kg. 1,4-DCB was detected in six surface soil samples above the Industrial PRG (approximately five percent of the total number of samples), all in the Montrose Former Plant Site.

4.3.8.2 1,4-Dichlorobenzene in Vadose Zone Soil

1,4-DCB was detected above laboratory MRLs in 305 of the 759 vadose zone soil analyses (approximately 40 percent) (Table 4-2 and Figure 4-11). Detectable 1,4-DCB concentrations in vadose zone soil ranged from 0.00097 to 21,000 mg/kg. 1,4-DCB was detected in 115 samples at concentrations greater than the Industrial PRG of 7.87 mg/kg (approximately 15 percent of the total number of samples).

1,4-DCB concentrations in the vadose zone were generally highest and most pervasive beneath the Montrose Former Plant Site. The maximum 1,4-DCB concentration of 21,000 mg/kg detected in vadose zone soil was at 15 feet bgs in soil boring FPS-13 in the Montrose Former Plant Site. 1,4-DCB concentrations in vadose zone soil in the Montrose Former Plant Site generally attenuate with depth. An SVE system is currently operating in the Montrose Former Plant Site to remove VOC-impacted vapor from vadose zone soil to a depth of approximately 42 feet bgs.

Additional areas where 1,4-DCB was detected above the Industrial PRG in vadose zone soil include:

- Montrose Former Tank Farm – 1,4-DCB was detected in three soil borings in the central portion of the Montrose Former Tank Farm at concentrations as high as 5,400 mg/kg. 1,4-DCB concentrations in vadose zone soil in the Montrose Former Tank Farm generally attenuate with depth.

- Stauffer Former ACD Plant – 1,4-DCB was detected in one soil boring in the Stauffer Former ACD Plant at concentrations as high as 33 mg/kg. 1,4-DCB concentrations in vadose zone soil beneath the Stauffer Former ACD Plant attenuate to 4.1 mg/kg at a depth of 41.5 feet.

1,4-DCB was not detected above the Industrial PRG in any of the other former Montrose or Stauffer facilities.

4.3.8.3 1,4-Dichlorobenzene in Saturated Zone Soil

1,4-DCB was detected above laboratory MRLs in 154 of the 313 saturated zone soil samples (approximately 49 percent) (Table 4-3, Figure 4-4, and Table D-12). Detectable 1,4-DCB concentrations in the saturated zone soil ranged from 0.0010 to 9,000 mg/kg. The maximum concentration of 1,4-DCB in saturated zone soil was detected at a depth of 61 feet bgs in reconnaissance boring RB-03 located in the Montrose Former Plant Site.

4.3.8.4 1,4-Dichlorobenzene in Groundwater

Alluvial Aquifer

The distribution of 1,4-DCB in alluvial aquifer groundwater at the Site is shown on Figure 4-12. 1,4-DCB was detected above laboratory MRLs in 276 of the 502 groundwater samples from the alluvial aquifer (approximately 55 percent) (Table 4-4). Detectable 1,4-DCB concentrations in alluvial aquifer groundwater ranged from 0.37 to 44,000 ug/l. The maximum 1,4-DCB concentration was detected October 2005 in alluvial aquifer monitor well MW-03 located immediately north of the Montrose Closed Ponds Area. The maximum concentration is greater than the MCL for 1,4-DCB of 75 ug/l. 1,4-DCB was detected in 146 samples above the MCL (approximately 29 percent of the total number of samples).

1,4-DCB was not detected in the alluvial aquifer upgradient of the former operational areas (Figure 4-12). 1,4-DCB was detected above the MCL in the alluvial aquifer beneath and downgradient of the Montrose Former Plant Site and Closed Ponds Area and in a localized area downgradient of the Stauffer Former BHC Cake Pile 3. The highest 1,4-DCB concentrations are

detected in the area immediately north of the Closed Ponds Area. 1,4-DCB concentrations decrease from the operational areas in the southern portion of the onsite area to the GWTS.

The extent of 1,4-DCB in the alluvial aquifer is well defined, with the exception of the area along the eastern Pioneer property boundary, based on the extensive groundwater monitoring network associated with the Site. The uncertainty in the eastern extent of 1,4-DCB in the alluvial aquifer represents a data gap, as identified in Section 9.0, which will be addressed during subsequent site characterization activities.

With the exception of an isolated detection in monitor well H-10A, 1,4-DCB was not detected above the MCL in alluvial aquifer groundwater downgradient of the GWTS. In the downgradient area, detectable concentrations of 1,4-DCB are limited to the area south of the Tronox Athens Road wellfield. 1,4-DCB is only detected above laboratory MRLs in the northern portion of the downgradient area near Las Vegas Wash in two monitor wells located near the Tronox Seep Area wellfield. Based on the substantial reduction of 1,4-DCB concentrations across the GWTS area, the GWTS appears to be effective at controlling the migration of 1,4-DCB in the alluvial aquifer groundwater (Figure 4-12).

Fine-Grained Upper Muddy Creek Formation

1,4-DCB was detected above laboratory MRLs in 45 of the 57 groundwater samples from the UMCf (approximately 79 percent) (Table 4-5 and Figure 4-6A). Detectable 1,4-DCB concentrations in UMCf groundwater ranged from 1.2 to 24,000 ug/l. The maximum 1,4-DCB concentration was detected in December 2006 in UMCf monitor well MC-MW-12. The maximum concentration is greater than the MCL. 1,4-DCB was detected in 35 samples above the MCL (approximately 61 percent of the total number of samples). The extent of 1,4-DCB in UMCf groundwater is not fully defined. The uncertainty in the extent of 1,4-DCB within the UMCf at the Site represents a data gap and additional characterization activities are ongoing to further delineate the extent of impacted groundwater in the UMCf, as further discussed in Section 9.0.

Coarse-Grained Upper Muddy Creek Formation

1,4-DCB was detected above laboratory MRLs in two of the 32 groundwater analyses from the UMCc (approximately six percent) (Table 4-6 and Figure 4-6B). Detectable 1,4-DCB concentrations in UMCc groundwater ranged from 2.6 to 3.8 ug/l. The detected concentrations are less than the MCL. Both of the 1,4-DCB detections were in October 2006 in UMCc monitor well MW-08. 1,4-DCB has not been detected in MW-08 since October 2006. As previously discussed, this anomalous detection may be the result of incomplete decontamination during sampling and the presence of 1,4-DCB in the UMCc will continue to be assessed through future groundwater monitoring of MW-08.

4.3.9   1,2,4-Trichlorobenzene in Soil and Groundwater

1,2,4-TCB was produced at the Site from 1947 to 1983. 1,2,4-TCB is a SVOC that is heavier than water. In comparison with other representative SRCs, 1,2,4-TCB has low to moderate solubility in water and is moderately mobile in the subsurface (Table 4-8). The distribution of 1,2,4-TCB in soil and groundwater is described below. Chemical cross-sections depicting the vertical distribution of 1,2,4-TCB in the subsurface are included in Appendix D, Figures D-5A through D-5B.

4.3.9.1 1,2,4-Trichlorobenzene in Surface Soil

1,2,4-TCB was detected above laboratory MRLs in 43 of the 112 surface soil samples (approximately 38 percent) (Table 4-1 and Figure 4-13). 1,2,4-TCB concentrations in surface soil ranged from 0.0029 to 21 mg/kg. The maximum 1,2,4-TCB concentration detected in surface soil was from boring FPS-06 located in the Montrose Former Plant Site. 1,2,4-TCB was not detected in surface soil above the Industrial PRG of 216 mg/kg.

4.3.9.2 1,2,4-Trichlorobenzene in Vadose Zone Soil

1,2,4-TCB was detected above laboratory MRLs in 252 of the 751 vadose zone soil samples (approximately 34 percent) (Table 4-2 and Figure 4-13). Detectable 1,2,4-TCB concentrations in vadose zone soil ranged from 0.00051 to 3,800 mg/kg. 1,2,4-TCB was only detected in six samples from two isolated soil borings in the Montrose Former Plant Site at concentrations greater than the Industrial PRG (less than one percent of the total number of samples) (Figure 4-13).

1,2,4-TCB concentrations in the vadose zone were generally highest and most pervasive beneath the Montrose Former Plant Site. The maximum 1,2,4-TCB concentration of 3,800 mg/kg was detected in vadose zone soil at a depth of 15 feet bgs in soil boring FPS-13 in the Montrose Former Plant Site. 1,2,4-TCB was not detected above the Industrial PRG in any other former Montrose or Stauffer facilities (Figure 4-13).

4.3.9.3 1,2,4-Trichlorobenzene in Saturated Zone Soil

1,2,4-TCB was detected above laboratory MRLs in 47 of the 313 saturated zone soil samples (approximately 15 percent) (Table 4-3, Figure 4-4, and Table D-13). Detectable 1,2,4-TCB concentrations in the saturated zone soil ranged from 0.0012 to 140 mg/kg. The maximum concentration of 1,2,4-TCB in saturated zone soil was detected at a depth of 106 feet bgs in reconnaissance boring RB-02 located approximately 250 feet north of the Montrose Former Plant Site.

4.3.9.4 1,2,4-Trichlorobenzene in Groundwater

Alluvial Aquifer

The distribution of 1,2,4-TCB in alluvial aquifer groundwater at the Site is shown on Figure 4-14. 1,2,4-TCB was detected above laboratory MRLs in 175 of the 502 groundwater samples from the alluvial aquifer (approximately 35 percent) (Table 4-4).   Detectable 1,2,4-TCB concentrations in alluvial aquifer groundwater ranged from 0.38 to 950 ug/l. The maximum 1,2,4-TCB concentration was detected in January 2007 in alluvial aquifer monitor well EC-03

located along the southern boundary of the Stauffer Former ACD Plant. The maximum concentration is greater than the MCL for 1,2,4-TCB of 70 ug/l. 1,2,4-TCB was detected in 55 samples above the MCL (approximately 11 percent of the total number of samples).

1,2,4-TCB was not detected in the alluvial aquifer upgradient of the former operational areas (Figure 4-14). 1,2,4-TCB was detected above the MCL in the alluvial aquifer in isolated areas north of the Montrose Closed Ponds Area and Stauffer Former ACD Plant, and an area extending from the northern boundary of the Pioneer property to the GWTS. The highest 1,2,4-TCB concentrations were detected in a localized area near the Stauffer Former ACD Plant. In some areas, the concentration of 1,2,4-TCB in the alluvial aquifer is uncertain due to elevated laboratory MRLs.

1,2,4-TCB was not detected above the MCL in alluvial aquifer groundwater downgradient of the GWTS. In the downgradient area, detectable concentrations of 1,2,4-TCB were generally limited to the area south of the monitor well MW-K1. 1,2,4-TCB was only detected above laboratory MRLs in the northern portion of the downgradient area near Las Vegas Wash in two monitor wells located near the Tronox Seep Area wellfield. Based on the substantial reduction of 1,2,4-TCB concentrations across the GWTS area, the GWTS appears to be effective at controlling the migration of 1,2,4-TCB in the alluvial aquifer groundwater (Figure 4-14).

Fine-Grained Upper Muddy Creek Formation

1,2,4-TCB was detected above laboratory MRLs in 14 of the 58 groundwater samples from the UMCf (approximately 24 percent) (Table 4-5 and Figure 4-6A). Detectable 1,2,4-TCB concentrations in UMCf groundwater ranged from 12 to 1,300 ug/l. The maximum 1,2,4-TCB concentration was detected in April 2005 in UMCf monitor well MCF-BW-08 (screened from 77 to 87 feet bgs) located along the southern boundary of the proposed BRC CAMU immediately north of CAPD Pond 7. The maximum concentration is greater than the MCL. 1,2,4-TCB was detected in five analyses above the MCL (approximately nine percent of the total number of samples). The extent of 1,2,4-TCB in UMCf groundwater is not fully defined. The uncertainty in the extent of 1,2,4-TCB in the UMCf at the Site represents a data gap and additional characterization activities are ongoing to further delineate the extent of impacted groundwater in the UMCf, as further described in Section 9.0.

Coarse-Grained Upper Muddy Creek Formation

1,2,4-TCB has not been detected above laboratory MRLs in the UMCc monitor wells.

4.3.10 Chloroform in Soil and Groundwater

Chloroform was identified as a waste material from the former facility operations.   Chloroform is a VOC that is heavier than water. In comparison with other representative SRCs, chloroform is highly soluble in water and mobile in the subsurface (Table 4-8). The distribution of chloroform in soil and groundwater is described below. Chemical cross-sections depicting the vertical distribution of chloroform in the subsurface are included in Appendix D, Figures D-6A and D-6B.

4.3.10.1 Chloroform in Surface Soil

Chloroform was detected above laboratory MRLs in 22 of the 56 surface soil samples (approximately 39 percent) (Table 4-1 and Figure 4-15). Detectable chloroform concentrations in surface soil ranged from 0.0009 to 0.068 mg/kg. Chloroform was predominantly detected in surface soil in the Montrose Former Plant Site, Tank Farm, and Closed Ponds Area. The maximum chloroform concentration detected in surface soil was from boring FPS-16S located in the Montrose Former Plant Site. Chloroform was not detected in surface soil above the Industrial PRG of 0.47 mg/kg.

4.3.10.2 Chloroform in Vadose Zone Soil

Chloroform was detected above laboratory MRLs in 256 of the 417 vadose zone soil samples (approximately 61 percent) (Table 4-2 and Figure 4-15). Detectable chloroform concentrations in vadose zone soil ranged from 0.00041 to 2,100 mg/kg. Chloroform was detected in 84 samples at concentrations greater than the Industrial PRG (approximately 20 percent of the total number of samples).

Chloroform concentrations in the vadose zone were generally highest beneath the Montrose Former Plant Site. The maximum chloroform concentration of 2,100 mg/kg was detected in boring FPS-13 at a depth of 15 feet bgs. The highest chloroform concentrations, however, were typically detected at depths greater than 30 feet bgs. An SVE system is currently operating in the northeast portion of the Montrose Former Plant Site to remove VOC-impacted vapor (including chloroform) from a depth of approximately 42 feet bgs (Section 2.4.2).

Additional areas where chloroform was detected above the Industrial PRG in vadose zone soil include:

- Montrose Closed Ponds Area – chloroform was detected above laboratory MRLs in all vadose zone soil samples collected from the 12 borings drilled in this area. Chloroform was detected above Industrial PRGs in seven of the 12 borings at concentrations as high as 12 mg/kg. Chloroform was detected at concentrations above the Industrial PRG in samples collected at depths of 20 feet bgs and greater.

- Montrose Former Tank Farm – Chloroform was detected above Industrial PRGs in vadose zone soil samples collected from seven of the 21 borings drilled in this area at concentrations as high as 34 mg/kg. Chloroform was detected at concentrations above the Industrial PRG in samples collected at depths of 20 feet bgs and greater.

- Northeast portion of the Pioneer property – Chloroform was detected above the Industrial PRG in the three borings drilled near the CAPD Ponds 3 and 5 and in the area northeast of these ponds at concentrations as high as 36 mg/kg. Chloroform was detected at concentrations above the Industrial PRG in samples collected at depths of 30 feet bgs and greater.

Chloroform was detected below the Industrial PRG in vadose zone soil samples collected from the Montrose Former Benzene Storage Tank Area and the former Stauffer facilities.

4.3.10.3 Chloroform in Saturated Zone Soil

Chloroform was detected above laboratory MRLs in 111 of the 166 saturated zone soil samples (approximately 67 percent) (Table 4-3, Figure 4-4, and Table D-14). Detectable chloroform concentrations in the saturated zone soil ranged from 0.00036 to 180 mg/kg. The maximum concentration of chloroform in saturated zone soil was detected at a depth of 61 feet bgs in reconnaissance boring RB-03 located in the Montrose Former Plant Site.

4.3.10.4 Chloroform in Groundwater

Alluvial Aquifer

The distribution of chloroform in alluvial aquifer groundwater at the Site is shown on Figure 4-16. Chloroform was detected above laboratory MRLs in 227 of the 329 groundwater samples from the alluvial aquifer (approximately 69 percent) (Table 4-4). Detectable chloroform concentrations in alluvial aquifer groundwater samples collected from monitor wells ranged from 0.35 to 110,000 ug/l. One higher detectable chloroform concentration was detected at 130,000 ug/l in the groundwater grab sample collected from the open hole boring FTF-10D. The maximum monitor well chloroform concentration was detected in March 2007 in alluvial aquifer monitor well H-38 located near the southeast corner of the inactive CAPD Pond 8. The maximum concentration is greater than the MCL for total trihalomethanes (which includes chloroform) of 80 ug/l. Chloroform was detected in 91 samples above the MCL (approximately 28 percent of the total number of samples).

Data from the ongoing monitoring indicate that the Montrose Closed Ponds Area is a potential source of VOCs, including chloroform to groundwater. The northeasternmost of the three downgradient monitor wells, MW-2, has exhibited a trend of increasing chloroform concentrations since the 1990's. Concentrations of chloroform have increased from approximately 3,000 ug/l to 96,000 ug/l in April 2008. These concentrations are indicative of the potential presence of NAPL. A similar trend, although at lesser concentrations, has also been observed at the adjacent downgradient monitor well, MW-3. A more detailed discussion of chloroform concentrations in the Closed Ponds Area including a preliminary evaluation of remedial alternatives has been prepared and submitted to NDEP (Geosyntec, 2008).

Chloroform was not detected in the alluvial aquifer monitor wells H-11 and H-13 located upgradient of the former facilities (Figure 4-16). Chloroform was detected above the MCL in the alluvial aquifer beneath large portions of the former facilities, beneath the proposed BRC CAMU, and near the GWTS. The highest chloroform concentrations were detected north of the Closed Ponds Area and in the northeast portion of the Pioneer property. In general, chloroform concentrations decrease from the former facilities in the southern portion of the onsite area to the GWTS. Exceptions include the area near alluvial aquifer monitor well H-38 (as previously identified) and in the western Slit Trench Area. In the western Slit Trench Area, chloroform was

detected at concentrations as high as 28,000 ug/l in grab groundwater samples collected in April 2005. These elevated chloroform concentrations relative to the surrounding area appear to indicate a separate source of chloroform in with the western Slit Trench Area (Figure 4-16).

The extent of chloroform in the alluvial aquifer is well defined, with the exception of the area along the eastern Pioneer property boundary, based on the extensive groundwater monitoring network associated with the Site. The uncertainty in the eastern extent of chloroform in the alluvial aquifer represents a data gap, as identified in Section 9.0, which will be addressed during subsequent site characterization activities. Additionally, chloroform was detected in alluvial aquifer grab samples WDE-01A, WDE-03, and WDE-04 above the MCL. These grab samples are located along a dry wash that exists east of the Pioneer property that may have historically received storm water runoff from the former facilities.

Chloroform was detected above the MCL in alluvial aquifer groundwater in an area downgradient of the GWTS extending approximately from the community of Pittman to the City of Henderson Water Reclamation Facility. The source of this chloroform to the alluvial aquifer groundwater is uncertain and may include contributions from sources outside of the CSM study area. Based on the substantial reduction in chloroform concentrations across the GWTS area, the GWTS appears to be effective at controlling the migration of chloroform in the alluvial aquifer groundwater (Figure 4-16).

Fine-Grained Upper Muddy Creek Formation

Chloroform was detected in UMCf groundwater at the Site (Figure 4-6A). Chloroform was detected above laboratory MRLs in 28 of the 31 groundwater samples from the UMCf (approximately 90 percent) (Table 4-5). Detectable chloroform concentrations in UMCf groundwater ranged from two to 140,000 ug/l. The maximum chloroform concentration of 140,000 ug/l was detected in October 2006 in UMCf monitor well MC-MW-10 (screened from 85 to 115 feet bgs) located approximately 800 feet north of the Montrose Former Plant Site. The maximum concentration is greater than the MCL. Chloroform was detected in 21 samples above the MCL (approximately 68 percent of the total number of samples). The uncertainty in the extent of chloroform in the UMCf at the Site represents a data gap and additional

characterization activities are ongoing to further delineate the extent of impacted water in the UMCf, as further described in Section 9.0.

Coarse-Grained Upper Muddy Creek Formation

Chloroform was detected above laboratory MRLs in one of the 16 groundwater samples from the UMCc (approximately six percent) (Table 4-6 and Figure 4-6B). This chloroform detection was 51 ug/l in October 2006 from monitor well MW-08. The detected concentration was less than the MCL. Chloroform has not been detected in MW-08 since October 2006. As previously discussed, this anomalous detection may be the result of incomplete decontamination during sampling and the presence of chloroform in the UMCc will continue to be assessed through future groundwater monitoring of MW-08.

4.3.11 Carbon Tetrachloride in Soil and Groundwater

Carbon tetrachloride was identified in the following waste streams at the Site: 1) the former Montrose production of desiccated chloral (potential constituent) (Converse, 1993); 2) the dilute sulfuric acid waste stream conveyed to the Montrose Closed Ponds Nos. 1, 3, and 4 from the Montrose operations; and 3) the former Stauffer chlorine liquefaction process (Weston, 1993). Carbon tetrachloride is a VOC that is heavier than water. In comparison with the other representative SRCs, carbon tetrachloride is highly soluble in water and relatively mobile in the subsurface (Table 4-8). The distribution of carbon tetrachloride in soil and groundwater is described below. Chemical cross-sections depicting the vertical distribution of carbon tetrachloride in the subsurface are included in Appendix D, Figures D-7A and D-7B.

4.3.11.1 Carbon Tetrachloride in Surface Soil

Carbon tetrachloride was detected above laboratory MRLs in eight of the 56 surface soil samples (approximately 14 percent), all in the Montrose Former Plant Site (Table 4-1 and Figure 4-17). Detectable carbon tetrachloride concentrations in surface soil ranged from 0.00060 to 0.40 mg/kg. The maximum carbon tetrachloride concentration detected in surface soil was from boring FPS-12. Carbon tetrachloride was not detected in surface soil samples above the Industrial PRG of 0.549 mg/kg.

4.3.11.2 Carbon Tetrachloride in Vadose Zone Soil

Carbon tetrachloride was detected above laboratory MRLs in 69 of the 417 vadose zone soil sample samples (approximately 17 percent) (Table 4-2 and Figure 4-17). Detectable carbon tetrachloride concentrations ranged from 0.00049 to 750 mg/kg. Carbon tetrachloride was detected in 22 vadose zone soil samples at concentrations greater than the Industrial PRG (5 percent of the total number of samples).

Carbon tetrachloride was primarily detected above the Industrial PRG in vadose zone soil samples collected at the Montrose Former Plant Site. The maximum carbon tetrachloride concentration (750 mg/kg) was detected in the vadose zone soil sample collected at 20 feet bgs from boring FPS-01. Carbon tetrachloride concentrations reported above the Industrial PRG in the Montrose Former Plant Site were generally found below 30 feet bgs. An SVE system is currently operating in the northeast portion of the Montrose Former Plant Site to remove VOC-impacted vapor (including carbon tetrachloride) from a depth of approximately 42 feet bgs (Section 2.4.2).

Carbon tetrachloride was also detected in vadose zone soil slightly above the Industrial PRG in one soil sample collected at 45 feet bgs from boring FTF-11D drilled in the Montrose Former Tank Farm.

Carbon Tetrachloride was not detected in vadose zone soil above laboratory MRLs in any of the former Stauffer facilities, and not above the Industrial PRG in the Montrose Closed Ponds Area or the Montrose Former Benzene Storage Tank.

4.3.11.3 Carbon Tetrachloride in Saturated Zone Soil

Carbon tetrachloride was detected above laboratory MRLs in 32 of the 166 saturated zone soil samples (approximately 19 percent) (Table 4-3, Figure 4-4, and Table D-15). Detectable carbon tetrachloride concentrations in the saturated zone soil ranged from 0.00069 to 95 mg/kg. The maximum concentration of carbon tetrachloride in saturated zone soil was detected at a depth of 96 feet bgs in reconnaissance boring RB-01 located in the Montrose Former Plant Site.

4.3.11.4 Carbon Tetrachloride in Groundwater

<u>Alluvial Aquifer</u>

The distribution of carbon tetrachloride in the alluvial aquifer is shown on Figure 4-18. Carbon tetrachloride was detected above laboratory MRLs in 25 of the 329 groundwater samples collected from the alluvial aquifer (approximately eight percent) (Table 4-4).   Detectable carbon tetrachloride concentrations in alluvial aquifer groundwater ranged from 0.63 to 1,500 ug/l. The maximum carbon tetrachloride concentration was detected in October 2006 in alluvial aquifer monitor well MW-02 located immediately northeast of the Montrose Closed Ponds Area. The maximum concentration is greater than the MCL for carbon tetrachloride of 5 ug/l. Carbon tetrachloride was detected in 91 samples above the MCL (approximately 21 percent of the total number of samples).

Carbon tetrachloride was not detected in the alluvial aquifer monitor wells H-11 and H-13 located upgradient of the former facilities. Carbon tetrachloride was detected above the MCL in the alluvial aquifer in the Montrose Closed Ponds Area, Former Tank Farm, and Former Plant Site, with the highest carbon tetrachloride concentrations detected in the in the Montrose Closed Ponds Area and Former Tank Farm. In general, carbon tetrachloride concentrations decrease from the former facilities in the southern portion of the onsite area to the GWTS, where it is currently not detected. The extent of carbon tetrachloride in the alluvial aquifer is uncertain in the northern portion of the Pioneer property due to elevated laboratory MRLs.

Carbon tetrachloride was detected above the MCL in alluvial aquifer groundwater in an area downgradient of the GWTS near the community of Pittman and the City of Henderson Water Reclamation Facility, and at an isolated location near monitor well ARP-6A downgradient of the Tronox Athens Road wellfield. The source of this carbon tetrachloride to the alluvial aquifer groundwater is uncertain and may include contributions from sources outside of the CSM study area.   In the remaining portions of the downgradient area, carbon tetrachloride is only sporadically detected at low concentrations; however, elevated laboratory MRLs equal to the MCL exist for many of the monitor wells.

Fine-Grained Upper Muddy Creek Formation

Carbon tetrachloride was detected above laboratory MRLs in 12 of the 32 groundwater samples collected from the UMCf (approximately 38 percent) (Table 4-5 and Figure 4-6A). Detectable carbon tetrachloride concentrations in UMCf groundwater ranged from 2.5 to 6,200 ug/l. Carbon tetrachloride was detected above the MCL in 10 samples (approximately 31 percent of the total number of samples). The maximum carbon tetrachloride concentration was detected in October 2006 in UMCf monitor well MC-MW-09 (screened from 90 to 120 feet bgs) located in the Montrose Former Plant Site.

The extent of carbon tetrachloride in the UMCf is uncertain due to elevated laboratory MRLs. The uncertainty in the extent of carbon tetrachloride in the UMCf at the Site represents a data gap and additional characterization activities are ongoing to further delineate the extent of impacted UMCf groundwater, as further described in Section 9.0.

Coarse-Grained Upper Muddy Creek Formation

Carbon tetrachloride has not been detected in groundwater samples collected from the UMCc.

4.3.12 Tetrachloroethene in Soil and Groundwater

PCE is a VOC that is heavier than water. In comparison with other representative SRCs, PCE is moderately soluble in water and relatively mobile in the subsurface (Table 4-8). The distribution of PCE in soil and groundwater is described below. Chemical cross-sections depicting the vertical distribution of PCE in the subsurface are included in Appendix D, Figures D-8A and D-8B.

4.3.12.1 Tetrachloroethene in Surface Soil

PCE was detected above laboratory MRLs in five of the 56 surface soil analyses (approximately nine percent) (Table 4-1 and Figure 4-19). Detectable PCE concentrations in surface soil ranged from 0.00062 to 0.016 mg/kg. The maximum PCE concentration detected in surface soil

was from boring SB-EC-01 located approximately 125 east of the Stauffer Former Lindane Plant. The maximum concentration is less than the PCE Industrial PRG of 1.31 mg/kg. PCE was not detected in surface soil samples above the Industrial PRG.

4.3.12.2 Tetrachloroethene in Vadose Zone Soil

PCE was detected above laboratory MRLs in 48 of the 417 vadose zone soil analyses (approximately 12 percent) (Table 4-2 and 4-19). Detectable PCE concentrations in vadose zone soil ranged from 0.00048 to 3.8 mg/kg. The maximum PCE concentration detected in vadose zone soil was from boring FPS-12D in the Montrose Former Plant Site. The maximum concentration is greater than the PCE Industrial PRG. PCE was detected in two samples at concentrations greater than the Industrial PRG (less than one percent of the total number of samples) in isolated areas in the Montrose Former Plant Site and Stauffer Former ACD Plant (Figure 4-19).

4.3.12.3 Tetrachloroethene in Saturated Zone Soil

PCE was detected above laboratory MRLs in four of the 166 saturated zone soil samples (approximately two percent) (Table 4-3, Figure 4-4, and Table D-16). Detectable PCE concentrations in the saturated zone soil ranged from 0.0015 to 1.7 mg/kg. The maximum concentration of PCE in saturated zone soil was detected at a depth of 96 feet bgs in reconnaissance boring RB-01 located in the Montrose Former Plant Site.

4.3.12.4 Tetrachloroethene in Groundwater

Alluvial Aquifer

The distribution of PCE in alluvial aquifer groundwater is shown on Figure 4-20. PCE was detected above laboratory MRLs in 91 of the 329 groundwater samples from the alluvial aquifer (approximately 28 percent) (Table 4-4). Detectable PCE concentrations in alluvial aquifer groundwater ranged from 0.32 to 1,200 ug/l. The maximum PCE concentration of 1,200 ug/l was detected in April 2005 from grab groundwater sample STA-05 collected from the alluvial

aquifer within the Slit Trench Area of the proposed BRC CAMU. PCE was detected in 45 groundwater samples at concentrations above the MCL for PCE of 5 ug/l (approximately 14 percent of the total number of samples).

PCE was not detected in the alluvial aquifer upgradient of the former facilities (Figure 4-20). PCE was detected above the MCL in the alluvial aquifer in the Montrose Closed Ponds Area, Former Tank Farm, and Former Plant Site; near the Stauffer Former ACD Plant; in the Slit Trench Area within the proposed BRC CAMU; and in the eastern portion of the GWTS. The highest PCE concentrations are detected in the Slit Trench Area. The extent of PCE in the alluvial aquifer is uncertain in the northern portion of the Pioneer property due to elevated laboratory MRLs associated with groundwater samples collected from this area.

With the exception of monitor wells MC-62, PC-40, and PC-67, PCE was not detected above the MCL in alluvial aquifer groundwater downgradient (north) of Warm Springs Road to the area near Las Vegas Wash. The downgradient extent of PCE exceeding the MCL in the alluvial aquifer downgradient of monitor wells MC-62, PC-40, and PC-67 was defined by the laboratory analytical results of groundwater samples collected from PC-31, PC-28, and PC-124, which contained concentrations of PCE ranging from less than the laboratory MRL to 0.58 ug/l. Based on the substantial reduction of PCE concentrations across the GWTS area, the GWTS appears to be effective at controlling the migration of PCE in the alluvial aquifer groundwater (Figure 4-20).

Fine-Grained Upper Muddy Creek Formation

PCE was detected in UMCf groundwater at the Site (Figure 4-6A). PCE was detected above laboratory MRLs in three of the 32 groundwater samples from the UMCf (approximately nine percent) (Table 4-5). Detectable PCE concentrations in UMCf groundwater ranged from 0.23 to 36 ug/l. The maximum PCE concentration was detected in October 2006 in UMCf monitor well MC-MW-11 (screened from 100.5 to 120.5 feet bgs) located in the Montrose Former Plant Site. PCE was detected in one groundwater sample collected from the UMCf above the MCL (approximately three percent of the total number of samples).

Coarse-Grained Upper Muddy Creek Formation

PCE has not been detected in groundwater samples collected from the UMCc.

4.3.13 BHC Isomers in Soil and Groundwater

BHC isomers have been detected in soil and groundwater samples collected from the Site. For the purposes of this CSM, the distributions of the most pervasive BHC isomers detected in soil and groundwater samples (i.e., alpha-, beta, and gamma-) were evaluated. BHC isomers are relatively insoluble in water and are solids at standard temperature ranges (Table 4-8). The solubility and mobility of BHC isomers can, however, be increased when present along with VOCs. The distribution of BHC isomers in soil and groundwater is described below. Chemical cross-sections depicting the vertical distribution of alpha-, beta-, and gamma-BHC in the subsurface are included in Appendix D, Figures D-9A through D-11B.

4.3.13.1 BHC Isomers in Surface Soil

BHC isomers were detected above laboratory MRLs in surface soil samples collected from the Site at frequencies ranging from approximately 20 percent (gamma-BHC isomer) to 86 percent (beta-BHC isomer), as indicated on Table 4-1. Of these three isomers, beta-BHC was the most frequently detected (Figure 4-21). Concentrations of BHC isomers in surface soil ranged from 0.0016 to 3,300 mg/kg. The highest concentrations of BHC isomers were detected in areas that have subsequently been covered with an asphalt cap (including the Former Lindane Plant and Former Cake Piles 1 and 2, as described in Section 2.4.3), which restricts potential exposure routes and the potential for transport of BHC isomers in these areas.

Figure 4-21 presents the distribution of beta-BHC in surface soils at areas of the Site not covered with asphalt caps (i.e., unpaved areas). Beta-BHC was selected as an indicator for the distribution of BHC-isomers, as it is detected at the highest concentration and at the greatest frequency in surface soil samples collected from the Site. Concentrations of BHC isomers located in unpaved areas range from 0.011 to 300 mg/kg. The highest concentration of the BHC isomers detected in surface soil samples collected in unpaved areas (beta-BHC detected at 300 mg/kg) was detected in sample SS-EC-65 located west of the Former Lindane Plant.

Concentrations of beta-BHC, ranging from 1.4 mg/kg (sample SS-EC-133) to 200 mg/kg (sample SS-EC-121), were reported in surface soil samples collected at the eastern perimeter of BHC Cake Pile 3 and southern perimeter of BHC Cake Pile 3 along the BHC Loader Route respectively. Additionally, notable concentrations of beta-BHC (150 mg/kg and 64 mg/kg) were reported in samples (SS-EC-78 and SS-EC-77, respectively) collected in the vicinity of the former Montrose Benzene Tank/Rail Car Loading Station.

A scope of work to further assess the horizontal and vertical distribution of BHC isomers in shallow soil at the Site and provide additional data to support the development of a site-specific risk assessment is proposed in the September 6, 2007 *Work Plan Addendum II – Shallow Soil Investigation, Revised Work Plan for Additional Vadose Zone Characterization, Former Stauffer Chemical Company Facility, Henderson, Nevada, NDEP Facility ID H-000536* (PES, 2007d). The proposed scope of work includes the collection of 30 surface soil samples and the completion of 33 shallow soil borings. The results of the assessment will be provided to NDEP under separate cover in accordance with the schedule described in the Work Plan.

4.3.13.2 BHC Isomers in Vadose Zone Soil

BHC isomers were detected above laboratory MRLs in soil samples collected from the vadose zone at frequencies ranging from approximately 25 percent (gamma-BHC isomer) to 34 percent (alpha-BHC isomer), as indicated on Table 4-2. The distribution of BHC isomers in the vadose zone at the Site is shown on Figure 4-22 (alpha-BHC), Figure 4-23 (beta-BHC), and Figure 4-24 (gamma-BHC).   The highest concentrations of BHC isomers (i.e., exceeding 100 mg/kg for individual BHC isomers) within the vadose zone were primarily detected in the following areas:

- Beneath Former BHC Cake Pile 1, where individual BHC isomers are present at concentrations up to 22,000 mg/kg (gamma-BHC isomer) at a depth of 7.5 feet bgs in soil boring SB-EC-04 and attenuate to 8.7 mg/kg at approximately 36 feet bgs.

- Beneath Former BHC Cake Pile 2, where individual BHC isomers are present at concentrations up to 2,700 mg/kg (alpha-BHC isomer) at a depth of 1.5 feet bgs in soil boring SB-EC-14 and attenuate to 440 mg/kg at approximately 40.5 feet bgs.

- Beneath the Former Lindane Plant, where individual BHC isomers are present at concentrations up to 2,700 mg/kg (alpha-BHC isomer) at a depth of approximately one foot bgs in soil boring FLP-06 and attenuate to 13 mg/kg at approximately 12 feet bgs.

- Immediately downgradient of BHC Cake Pile 3, where individual BHC isomers are present at concentrations up to 2,700 mg/kg (alpha-BHC isomer) at a depth of approximately 7.5 feet bgs in the soil boring for monitor well EC-10 and attenuate to 51 mg/kg at approximately 40.5 feet bgs.

Other areas where individual BHC isomers were detected at relatively elevated concentrations within the vadose zone include the Montrose Former Plant Site (a soil sample collected at a depth of approximately 21 feet bgs from soil boring FPS-13 contained alpha-BHC at a concentration of 2,200 mg/kg) and along the former wastewater conveyance piping east of the Former Lindane Plant (a soil sample collected at a depth of approximately 14 feet bgs from soil boring B-2 contained alpha-BHC at a concentration of 41 mg/kg). Deeper sampling for BHC isomers in these areas has not been performed.

4.3.13.3 BHC Isomers in Saturated Zone Soil

BHC isomers were detected above laboratory MRLs in 47 of the 166 saturated zone soil samples (approximately 28 percent) (Table 4-3, Figure 4-4, and Tables D-17 through D-19). Concentrations of individual BHC isomers in the saturated zone soil ranged from 0.0016 to 2.0 mg/kg. The maximum concentration of alpha-BHC in saturated zone soil was detected at a depth of 106 feet bgs in reconnaissance boring RB-02 located approximately 250 feet north of the Montrose Former Plant Site.

4.3.13.4 BHC Isomers in Groundwater

Alluvial Aquifer

The distribution of BHC isomers in alluvial aquifer groundwater at the Site is shown on Figure 4-25 (alpha-BHC), Figure 4-26 (beta-BHC), and Figure 4-27 (gamma-BHC). BHC isomers were detected above laboratory MRLs in groundwater samples collected from the alluvial aquifer at frequencies ranging from approximately 36 percent (gamma-BHC isomer) to 71 percent (beta-BHC isomer), as indicated on Table 4-4.

BHC isomers are present in the alluvial aquifer at concentrations exceeding one ug/l beneath former Site facilities, extending beneath the proposed BRC CAMU, and near the GWTS

(Figures 4-25, 4-26, and 4-27). The extent of BHC isomers in the alluvial aquifer is well defined except in the area along the northeastern Pioneer property boundary (e.g., the northeastern extent of alpha BHC at concentrations of 57 ug/l in alluvial aquifer monitor well AA-MW-07 located at the northeast corner of the on-Site area is not fully defined). The extent of BHC isomers in the alluvial aquifer northeast of the Site represents a data gap, as identified in Section 9.0, which will be addressed during subsequent site characterization activities. The highest concentrations of BHC isomers in the alluvial aquifer are generally present in three areas:

- In the vicinity of the Former Lindane Plant and Former BHC Cake Piles 1 and 2, where individual BHC isomers are present at concentrations up to 480 ug/l (alpha-BHC isomer) in groundwater samples collected from alluvial aquifer monitor well EC-03. The concentration of BHC isomers in the alluvial aquifer exhibit appreciable declines downgradient of this area (e.g., alpha-BHC is present at 13 ug/l in alluvial aquifer monitor well EC-07 located approximately 600 feet downgradient of EC-03);

- Immediately downgradient of Former Wastewater Pond 1, where individual BHC isomers are present at concentrations up to 370 ug/l (alpha-BHC isomer) in groundwater samples collected from alluvial aquifer monitor well AA-BW-08A, and

- The Former Slit Trench Area of the proposed BRC CAMU, where individual BHC isomers are present at concentrations up to 53 ug/l (alpha-BHC isomer) in grab groundwater samples collected from the alluvial aquifer (sample location B-5N). This finding is consistent with findings from the CSM prepared for the proposed CAMU, which indicate "it appears that sources of alpha-BHC impacts to groundwater occur south of the CAMU as well as within the interior of the CAMU, in the STA [Slit Trench Area]" (BRC, 2007).

BHC isomers in the alluvial aquifer extend from the Former Wastewater Pond 1 (i.e., the northern boundary of the on-Site area) and Former Slit Trench Area of the Proposed BRC CAMU to the GWTS, where concentrations of individual BHC isomers range up to 86 ug/l (alpha-BHC isomer at Well G). Although upgrades to the GWTS to treat for pesticides have only been conducted recently, the concentrations of BHC isomers immediately downgradient of the GWTS are generally lower in comparison with upgradient concentrations. For example, concentrations of alpha-BHC in alluvial aquifer groundwater monitor wells decrease from approximately 130 ug/l upgradient of the GWTS (well AA-BW-04A) to concentrations ranging from 0.20 to 1.1 ug/l immediately downgradient of the GWTS (wells MC-46, MC-50, MC-51, and MC-53). As shown on Figure 4-27, the presence of gamma-BHC in the alluvial aquifer downgradient of the GWTS at concentrations exceeding the MCL of 0.2 ug/l appears to be

limited to an area extending from approximately Warm Springs Road to Boulder Highway (i.e., encompassing monitor wells MC-62 and PC-40). The downgradient extent of this area is defined by alluvial aquifer monitor wells MW-R, PC-31, and PC-64, where gamma-BHC was not detected at or above the laboratory's MRL (ranging from 0.095 to 0.1 ug/l). Concentrations of beta-BHC (for which an MCL has not been established) downgradient of the GWTS (ranging from less than the laboratory reporting limit to 18 ug/l [at monitor well MC-62]) also exhibit reductions across the GWTS, although less than the reductions observed for the alpha- and gamma-isomers.

Fine-Grained Upper Muddy Creek Formation

BHC isomers were detected above laboratory MRLs in groundwater samples collected beneath the alluvial aquifer within the UMCf at frequencies ranging from approximately 55 percent (beta-BHC isomer) to 74 percent (alpha-BHC isomer), as indicated on Table 4-5. The highest concentrations of BHC isomers in the UMCf were detected immediately downgradient of the Former Wastewater Pond 1, where individual BHC isomers were present at concentrations up to 380 ug/l (alpha-BHC isomer) in groundwater samples collected from monitor well MCF-BW-08 (screened from 77 to 87 feet in the UMCf). Relatively elevated concentrations of BHC isomers were also detected in UMCf monitor well MC-MW-11 located downgradient of the Former ACD Plant, Former Lindane Plant, and Former BHC Cake Piles 1 and 2 at concentrations up to 17 ug/l (alpha-BHC isomer). The vertical characterization of groundwater conditions below the alluvial aquifer (i.e. within the fine-grained UMCf which exhibits the physical and hydraulic properties of a regional aquitard) is identified as a data gap. The approach and objectives for additional vertical characterization of groundwater conditions will be developed based on discussion with NDEP.

Coarse-Grained Upper Muddy Creek Formation

Detections of BHC isomers in the UMCc are limited to sporadic detections of the alpha- and delta-isomers, which were reported at estimated values (below the laboratory MRLs) ranging from 0.023 to 0.073 ug/l (Table 4-6). While equipment blanks were not analyzed for OCPs as part of the groundwater monitoring event associated with estimated detections of alpha- and delta-BHC isomers in the UMCc, other groundwater sampling events at the site have

documented that such low level estimated concentrations are associated with cross-contamination of sampling equipment (e.g., estimated concentrations of individual BHC isomers detected in equipment blank samples collected during the Phase I and Phase II Site-Wide Groundwater Sampling event ranged from 0.033 to 0.054 ug/l). BHC isomers will continue to be monitored for in the UMCc through future groundwater monitoring events.

4.3.14 <u>4,4'-DDT in Soil and Groundwater</u>

4,4'-DDT was a raw product used by Montrose to produce chloral at the Site (Converse, 1993). 4,4'-DDT is a pesticide that is heavier than water. Among the representative SRCs, 4,4'-DDT has a low solubility in water and is relatively immobile in the subsurface (Table 4-8). The distribution of 4,4'-DDT in soil and groundwater is described below. Chemical cross-sections depicting the vertical distribution of 4,4'-DDT in the subsurface are included in Appendix D, Figures D-12A and D-12B.

4.3.14.1 4,4'-DDT in Surface Soil

4,4'-DDT was detected above laboratory MRLs in 80 of the 202 surface soil samples (approximately 40 percent) (Table 4-1 and Figure 4-28). Detectable 4,4'-DDT concentrations in surface soil ranged from 0.0033 to 160 mg/kg. The maximum 4,4'-DDT concentration detected in surface soil was from boring FPS-10 located in the Montrose Former Plant Site. The maximum concentration is greater than the 4,4'-DDT Industrial PRG of 7.02 mg/kg. 4,4'-DDT was detected in 11 surface soil samples above the Industrial PRG, all in the Montrose Former Plant Site (approximately 5 percent of the total number of samples).

4.3.14.2 4,4'-DDT in Vadose Zone Soil

4,4'-DDT was detected above laboratory MRLs in 132 of the 371 vadose zone soil samples (approximately 36 percent) (Table 4-2 and Figure 4-28). Detectable 4,4'-DDT concentrations in vadose zone soil ranged from 0.0035 to 1,300 mg/kg. 4,4'-DDT was detected in 29 samples at concentrations greater than the Industrial PRG (approximately eight percent of the total number of samples).

4,4'-DDT was detected above the Industrial PRG in vadose zone soil primarily in the Montrose Former Plant Site. The maximum 4,4'-DDT concentration (1,300 mg/kg) was detected at a depth of six feet bgs in boring FPS-11. 4,4'-DDT concentrations detected above the Industrial PRG were generally found at depths less than 20 feet bgs with two exceptions. 4,4'-DDT was detected above the Industrial PRG in borings FPS-01 and FPS-11 at depths of 30 and 40 feet bgs, respectively. In most areas, 4,4'-DDT concentrations in vadose zone soil attenuate with depth in the Montrose Former Plant Site.

4,4'-DDT was detected above the Industrial PRG in the Stauffer Former ACD Plant in two samples collected from boring SB-EC-13 at depths of 27.5 feet bgs (290 mg/kg) and 40.5 feet bgs (53 mg/kg) drilled in this area.

4,4'-DDT was sporadically detected at concentrations below the Industrial PRG in vadose zone soil samples collected from the Montrose Former Benzene Storage Tank (one sample at 7.5 feet bgs) and west of the Montrose Former Plant Site in soil boring B-3 at 11 feet bgs and reconnaissance boring RB-04 at 30 feet bgs. 4,4'-DDT was not detected in vadose zone soil in the Montrose Closed Ponds Area or any former Stauffer facility other than Former ACD Plant.

4.3.14.3 4,4'-DDT in Saturated Zone Soil

4,4'-DDT was detected above laboratory MRLs in 24 of the 166 saturated zone soil samples (approximately 15 percent) (Table 4-3, Figure 4-4, and Table D-20). 4,4'-DDT was detected in saturated zone soil at concentrations ranging from 0.0039 to 26 mg/kg. The maximum concentration of 4,4'-DDT in saturated zone soil was detected at a depth of 106 feet bgs in reconnaissance boring RB-02 located approximately 200 feet north of the Montrose Former Plant Site.

4.3.14.4 4,4'-DDT in Groundwater

Alluvial Aquifer

The distribution of 4,4'-DDT in alluvial groundwater is shown on Figure 4-29. 4,4'-DDT was detected above laboratory MRLs in 20 of the 276 groundwater samples from the alluvial aquifer (approximately seven percent) (Table 4-4). Detectable 4,4'-DDT concentrations in alluvial aquifer groundwater ranged from 0.020 to 780 ug/l. The maximum 4,4'-DDT concentration was detected in October 2006 in alluvial aquifer monitor well EC-09 located along the northern boundary of the Stauffer Former Phosphoric Acid Pond and Leach Field. An MCL for 4,4'-DDT has not been established.

4,4'-DDT was not detected in the alluvial aquifer upgradient of the former operational areas. 4,4'-DDT was detected in alluvial aquifer groundwater three isolated areas: 1) north of the Montrose Closed Ponds Area, 2) in the vicinity of the Stauffer Former Phosphoric Acid Pond and Leach Field, and 3) in the northeast portion of the Pioneer property. The extent of 4,4'-DDT in the alluvial aquifer is well defined. The highest 4,4'-DDT concentrations are detected in the vicinity of the Former Phosphoric Acid Pond and Leach Field. 4,4'-DDT was not detected near or downgradient of the GWTS. 4,4'-DDT was detected downgradient of the GWTS at a concentration of 0.12 ug/l in one isolated monitor well, MW-S, located northwest of the City of Henderson Water Reclamation Facility.

Fine-Grained Upper Muddy Creek Formation

4,4'-DDT was detected above laboratory MRLs in 11 of the 31 groundwater samples from the UMCf (approximately 36 percent) (Figure 4-6A and Table 4-5). Detectable 4,4'-DDT concentrations in UMCf groundwater ranged from 0.032 to 100 ug/l. The maximum 4,4'-DDT concentration was detected in December 2006 in UMCf monitor well MC-MW-12 located approximately 800 feet northeast of the Montrose Former Plant Site.

<u>Coarse-Grained Upper Muddy Creek Formation</u>

4,4'-DDT was detected above laboratory MRLs in one of the 16 groundwater samples from the UMCc (approximately six percent) (Table 4-6 and Figure 4-6B). The detection of 4,4'-DDT occurred in October 2006 in monitor well MW-08 at a concentration of 0.040 ug/l. 4,4'-DDT has not been detected in MW-08 since October 2006. As previously discussed, this anomalous detection may be the result of incomplete decontamination during sampling and the presence of 4,4'-DDT in the UMCc will continue to be assessed through future groundwater monitoring of MW-08.

4.3.15 4,4'-DDE in Soil and Groundwater

4,4'-DDE is typically found in small quantities mixed with 4,4'-DDT. 4,4'-DDE is a pesticide that is heavier than water. Among the representative SRCs, 4,4'-DDE has low solubility in water and is relatively immobile in the subsurface (Table 4-8). The distribution of 4,4'-DDE in soil and groundwater is described below. Chemical cross-sections depicting the vertical distribution of 4,4'-DDE in the subsurface are included in Appendix D, Figures D-13A and D-13B.

4.3.15.1 4,4'-DDE in Surface Soil

4,4'-DDE was detected above laboratory MRLs in 120 of the 205 surface soil analyses (approximately 59 percent) (Table 4-1 and Figure 4-30). Detectable 4,4'-DDE concentrations in surface soil ranged from 0.0054 to 49 mg/kg. The maximum 4,4'-DDE concentration detected in surface soil was from boring FPS-02 located in the Montrose Former Plant Site. The maximum concentration is greater than the 4,4'-DDE Industrial PRG of 7.02 mg/kg. 4,4'-DDE was detected in 10 surface soil samples above the Industrial PRG (approximately five percent of the total number of samples).

4.3.15.2 4,4'-DDE in Vadose Zone Soil

4,4'-DDE was detected above laboratory MRLs in 132 of the 371 vadose zone soil analyses (approximately 36 percent) (Table 4-2 and Figure 4-30). Detectable 4,4'-DDE concentrations in

vadose zone soil ranged from 0.0015 to 170 mg/kg. 4,4'-DDE was detected in 23 samples at concentrations greater than the Industrial PRG (approximately six percent of the total number of samples).

4,4'-DDE concentrations detected above the Industrial PRG in vadose zone soil samples were limited to the Montrose Former Plant Site. The maximum 4,4'-DDE concentration (170 mg/kg) was detected at a depth of 20 feet bgs in boring FPS-11. 4,4'-DDE concentrations detected above the Industrial PRG were generally detected at depths less than 20 feet bgs with two exceptions.   4,4'-DDE was detected above the Industrial PRG in borings FPS-01 and FPS-11 at depths of 30 and 40 feet bgs, respectively.   In most areas in the Montrose Former Plant Site, 4,4'-DDE concentrations in vadose zone soil attenuate with depth.

4,4'-DDE was sporadically detected at low concentrations less than the Industrial PRG in vadose zone soil samples collected from the Montrose Former Tank Farm, the northern portion of the Montrose Closed Ponds Area, west of the Montrose Former Plant Site in soil boring B3 at 14 feet bgs, near the Inactive Benzene Underground Storage Tanks in soil boring SB-EC-03 at a depth of 7.5 feet bgs, and on the northern perimeter of the ACD Drum Burial Waste Management Area in soil boring EC-09 at 7.5 feet bgs.

4.3.15.3 4,4'-DDE in Saturated Zone Soil

4,4'-DDE was detected above laboratory MRLs in 24 of the 166 saturated zone soil samples (approximately 15 percent) (Table 4-3, Figure 4-4, and Table D-21). Detectable 4,4'-DDE concentrations in saturated zone soil ranged from 0.0015 to 21 mg/kg. The maximum concentration of 4,4'-DDE in saturated zone soil was detected at a depth of 106 feet bgs in reconnaissance boring RB-02 located approximately 200 feet north of the Montrose Former Plant Site.

4.3.15.4 4,4'-DDE in Groundwater

Alluvial Aquifer

The distribution of 4,4'-DDE in alluvial aquifer groundwater at the Site is shown in Figure 4-31. 4,4'-DDE was detected above laboratory MRLs in six of the 275 groundwater samples from the alluvial aquifer (approximately two percent) (Table 4-4). Detectable 4,4'-DDE concentrations in alluvial aquifer groundwater ranged from 0.020 to 0.31 ug/l. The maximum 4,4'-DDE concentration was detected in March 2007 in alluvial aquifer monitor well B-13 located along the southern boundary of the CAPD Pond 7.   An MCL for 4,4'-DDE has not been established.

4,4'-DDE was detected in two isolated areas: 1) in the Montrose Former Tank Farm, and 2) in the northeast portion of the Pioneer property. The extent of 4,4'-DDE in the alluvial aquifer is well defined. 4,4'-DDE was generally not detected in the alluvial aquifer upgradient of the former operational areas. 4,4'-DDE was not detected near or downgradient of the GWTS.

Fine-Grained Upper Muddy Creek Formation

4,4'-DDE was detected above laboratory MRLs in five of the 30 groundwater samples from the UMCf (approximately 17 percent) (Table 4-5 and Figure 4-6A). 4,4'-DDE was detected in the UMCf beneath the central portion of the Pioneer property. Detectable 4,4'-DDE concentrations in UMCf groundwater ranged from 0.11 to 150 ug/l. The maximum 4,4'-DDE concentration was detected in December 2006 in UMCf monitor well MC-MW-12 located approximately 800 feet northeast of the Montrose Former Plant Site.

Coarse-Grained Upper Muddy Creek Formation

4,4'-DDE has not been detected above laboratory MRLs in the UMCc.

4.3.16 Carbophenothion in Soil and Groundwater

Carbophenothion is an organophosphorous pesticide that was produced historically by Stauffer at the Site. In comparison with other representative SRCs, carbophenothion is relatively insoluble in water and relatively immobile in the subsurface (Table 4-8). The distribution of carbophenothion in soil and groundwater is described below. Chemical cross-sections depicting the vertical distribution of carbophenothion in the subsurface are included in Appendix D, Figures D-14A and D-14B.

4.3.16.1 Carbophenothion in Surface Soil

Carbophenothion was detected above laboratory MRLs in 21 of the 32 surface soil samples (approximately 66 percent) (Table 4-1 and Figure 4-32). Carbophenothion concentrations in surface soil ranged from 0.0066 to 6,600 mg/kg. The highest concentrations of carbophenothion in near surface soil samples were detected in areas that have subsequently been covered with an asphalt cap (as described in Section 2.4.3), which restricts potential exposure routes and the potential for surface transport of carbophenothion in these areas. For example, the maximum carbophenothion concentration detected in surface soil was from boring ACD-6 located within the capped area of the Stauffer Former ACD Plant, where concentrations of carbophenothion attenuate to less that the laboratory MRL of 0.020 mg/kg at 11 feet bgs. Concentrations of carbophenothion detected in surface soil samples from unpaved areas range from less than the laboratory MRL of 0.020 mg/kg to 2.1 mg/kg (EC-7). An Industrial PRG has not been established for carbophenothion.

4.3.16.2 Carbophenothion in Vadose Zone Soil

Carbophenothion was detected above laboratory MRLs in 23 of the 70 vadose zone soil analyses (approximately 33 percent) (Table 4-2 and Figure 4-32). Detectable carbophenothion concentrations in vadose zone soil ranged from 0.012 to 600 mg/kg. The maximum carbophenothion concentration in vadose zone soil was detected at a depth of four feet bgs in boring ACD-9 in the Stauffer Former ACD Plant and attenuates to 21 mg/kg at a depth of approximately 11 feet bgs.

4.3.16.3 Carbophenothion in Saturated Zone Soil

Carbophenothion was not analyzed for in saturated zone soil.

4.3.16.4 Carbophenothion in Groundwater

Alluvial Aquifer

The distribution of carbophenothion in alluvial aquifer groundwater is shown on Figure 4-33. Carbophenothion was detected above laboratory MRLs in four of the 89 groundwater samples collected from the alluvial aquifer (approximately five percent) (Table 4-4). As indicated on Figure 4-33, detectable concentrations of carbophenothion in the alluvial aquifer ranged from 0.11 to 56 ug/l. The maximum carbophenothion concentration was detected in October 2006 in alluvial aquifer monitor well EC-09 located along the northern boundary of the Stauffer Former Phosphoric Acid Pond and Leach Field.   As shown on Figure 4-33, carbophenothion does not appear to extend appreciable distances past the northern Site boundary and is not detected in the vicinity of or downgradient of the GWTS at concentrations at or above laboratory MRLs. An MCL for carbophenothion has not been established.

Fine-Grained Upper Muddy Creek Formation

Carbophenothion was detected above laboratory MRLs in one of the eight groundwater samples from the UMCf (approximately 12 percent) (Table 4-5 and Figure 4-6A). As shown on Figure 4-6A, carbophenothion was detected in April 2005 at a concentration of 0.48 ug/l in UMCf monitor well MCF-BW-11A (screened from 57 to 72 feet bgs), which is located along the southern boundary of the proposed BRC CAMU immediately north of inactive ACD Pond 2.

Coarse-Grained Upper Muddy Creek Formation

Carbophenothion has not been detected above laboratory MRLs in the UMCc.

4.3.17 2,3,7,8-Tetrachlorodibenzo-p-Dioxin in Soil and Groundwater

TCDD was identified as a waste material from the former Montrose operations. TCDD is heavier than water. Among the representative SRCs, TCDD is relatively insoluble in water and relatively immobile in the subsurface (Table 4-8). The distribution of TCDD in soil and groundwater is described below. Chemical cross-sections were not prepared for TCDD due to the limited vertical depth of sampling.

4.3.17.1 2,3,7,8-Tetrachlorodibenzo-p-Dioxin in Surface Soil

TCDD was detected above laboratory MRLs in eight of the 23 surface soil samples (approximately 35 percent) (Table 4-1 and Figure 4-34). Detectable TCDD concentrations in surface soil ranged from 6.1×10^{-7} to 2.45×10^{-5} mg/kg. The maximum TCDD concentration detected in surface soil was from boring SB-EC-14 located in the Stauffer Former BHC Cake Pile 2 area, which is currently covered with an asphalt cap. The maximum concentration is greater than the TCDD Industrial PRG of 1.6×10^{-5} mg/kg. TCDD was detected in two surface soil samples above the Industrial PRG (approximately nine percent of the total number of samples).

4.3.17.2 2,3,7,8-Tetrachlorodibenzo-p-Dioxin in Vadose Zone Soil

Only one soil sample has been analyzed in the vadose zone soil (at depths greater than 2 feet) for TCDD. TCDD was not detected above laboratory MRLs in this sample at 5 feet bgs in soil boring SB-EC-12 located in the Stauffer Former ACD Plant (Figure 4-34).

4.3.17.3 2,3,7,8-Tetrachlorodibenzo-p-Dioxin in Saturated Zone Soil

TCDD was not analyzed for in saturated zone soil.

4.3.17.4 2,3,7,8-Tetrachlorodibenzo-p-Dioxin in Groundwater

Alluvial Aquifer

TCDD was detected in one sample from the alluvial aquifer at the Site (Table 4-4 and Figure 4-35). TCDD was detected in an isolated area at a concentration of 4.1×10^{-4} ug/l in April 2005 in monitor well AA-BW-08A, located along the southern boundary of the proposed BRC CAMU immediately north of the CAPD Pond 7. This detection of TCDD exceeds the MCL of 3.0×10^{-5}. TCDD was not detected near or downgradient of the GWTS.

Fine-Grained Upper Muddy Creek Formation

2,3,7,8-TCDD has not been detected above laboratory MRLs in the UMCf.

Coarse-Grained Upper Muddy Creek Formation

2,3,7,8-TCDD has not been detected above laboratory MRLs in the UMCc.

4.3.18 Bis(4-Chlorophenyl) Disulfide in Soil and Groundwater

Bis(4-chlorophenyl) disulfide was identified as a waste material in the former Stauffer operations. In comparison with other representative SRCs, bis(4-chlorophenyl) disulfide is relatively insoluble in water and relatively immobile in the subsurface (Table 4-8). The distribution of bis(4-chlorophenyl) disulfide in soil and groundwater is described below. Chemical cross-sections depicting the vertical distribution of bis(4-chlorophenyl) disulfide in the subsurface are included in Appendix D, Figures D-15A and D-15B.

4.3.18.1 Bis(4-Chlorophenyl) Disulfide in Surface Soil

Bis(4-chlorophenyl) disulfide was detected above laboratory MRLs in four of the 41 surface soil samples (approximately 10 percent) (Table 4-1 and Figure 4-36). Detectable bis(4-chlorophenyl) disulfide concentrations in surface soil ranged from 0.31 to 17 mg/kg. The maximum bis(4-chlorophenyl) disulfide concentration detected in surface soil was from the soil boring for monitor well EC-08 located adjacent to the Former ACD Drum Burial Waste Management Area. An Industrial PRG for bis(4-chlorophenyl) disulfide has not been established.

4.3.18.2 Bis(4-Chlorophenyl) Disulfide in Vadose Zone Soil

Bis(4-chlorophenyl) disulfide was detected above laboratory MRLs in 13 of the 278 vadose zone soil samples (approximately five percent) (Table 4-2). Detectable bis(4-chlorophenyl) disulfide concentrations in vadose zone soil ranged from 0.28 to 6,000 mg/kg (Figure 4-36). The maximum bis(4-chlorophenyl) disulfide concentration in vadose zone soil was detected at a depth of 7.5 feet bgs in boring SB-EC-12 located in the Stauffer Former ACD Plant and attenuates to 650 mg/kg at a depth of approximately 46 feet bgs.

4.3.18.3 Bis(4-Chlorophenyl) Disulfide in Saturated Zone Soil

Bis(4-chlorophenyl) disulfide was not detected in saturated zone soil (Table D-22).

4.3.18.4 Bis(4-Chlorophenyl) Disulfide in Groundwater

Alluvial Aquifer

The distribution of bis(4-chlorophenyl) disulfide in alluvial aquifer groundwater is shown on Figure 4-37. Bis(4-chlorophenyl) disulfide was detected above laboratory MRLs in 11 of the 113 groundwater samples collected from the alluvial aquifer (approximately 10 percent) (Table 4-4). As indicated on Figure 4-37, detectable concentrations of bis(4-chlorophenyl) disulfide in alluvial aquifer groundwater ranged from 10 to 3,900 ug/l. The maximum bis(4-chlorophenyl) disulfide concentration was detected in April 2005 in alluvial aquifer monitor well AA-BW-12A located

along the southern boundary of the proposed BRC CAMU. As shown on Figure 4-37, bis(4-chlorophenyl) disulfide extends beneath the proposed BRC CAMU towards the GWTS. Bis(4-chlorophenyl) disulfide was not detected in the alluvial aquifer at concentrations at or above the laboratory MRL within the GWTS extraction wells or downgradient of the GWTS. An MCL for bis(4-chlorophenyl) disulfide has not been established.

Fine-Grained Upper Muddy Creek Formation

Bis(4-chlorophenyl) disulfide was detected in one sample from the UMCf at the Site (Table 4-5 and Figure 4-6A). Bis(4-chlorophenyl) disulfide was detected at a concentration of 7.2 ug/l in October 2006 in monitor well MC-MW-11, which is located approximately 150 feet northeast of the Stauffer Former ACD Plant.

Coarse-Grained Upper Muddy Creek Formation

Bis(4-chlorophenyl) disulfide has not been detected above laboratory MRLs in the UMCc.

4.3.19 Organic Acids in Soil and Groundwater

The following organic acids have been identified as Stauffer SRCs and have been detected in soil and groundwater samples collected from the Site: para-chlorobenzene sulfonic acid, benzenesulfonic acid, DMPT, diethyl phosphorodithioic acid, and phthalic acid. Of these five organic acids, DMPT was detected at the greatest frequency in soil and groundwater samples collected from the Site and is, therefore, used as an indicator for the purpose of evaluating the distribution of organic acids in this CSM. DMPT is highly solubility in water and mobile in the subsurface (Table 4-8). The distribution of DMPT in soil and groundwater is described below. Chemical cross-sections depicting the vertical distribution of DMPT in the subsurface are included in Appendix D, Figures D-16A and D-16B.

4.3.19.1 Organic Acids in Surface Soil

DMPT was detected above laboratory MRLs in three of the 36 surface soil samples (approximately eight percent) (Table 4-1 and Figure 4-38). DMPT concentrations in surface soil ranged from 6.1 to 32 mg/kg. The maximum DMPT concentration detected in surface soil was from boring EC-10 located along the northern margin of the Stauffer Former BHC Cake Pile 3. At this location, DMPT concentrations attenuate to less than the laboratory MRL of 2.5 mg/kg at a depth of 26 feet bgs.

4.3.19.2 Organic Acids in Vadose Zone Soil

DMPT was detected above laboratory MRLs in 15 of the 209 vadose zone soil samples (approximately seven percent) (Table 4-2). Detectable DMPT concentrations in vadose zone soil ranged from 3.0 to 38 mg/kg (Figure 4-38). The maximum DMPT concentration in vadose zone soil was detected at a depth of five feet bgs in boring FPS-11S in the Montrose Former Plant Site and attenuates to less than the laboratory MRL of 2.5 mg/kg at a depth of approximately 10 feet bgs. DMPT was also detected in vadose zone soil in the Stauffer Former ACD Plant, Former Phosphoric Acid Pond and Leach Field, ACD Drum Burial Waste Management Area, BHC Cake Pile 3, and Former Tank Farm (Figure 4-38).

4.3.19.3 Organic Acids in Saturated Zone Soil

DMPT was not detected in saturated zone soil (Appendix D, Table D-23).

4.3.19.4 Organic Acids in Groundwater

Alluvial Aquifer

The distribution of DMPT in alluvial aquifer groundwater is shown on Figure 4-39. DMPT was detected above laboratory MRLs in 70 of the 253 groundwater samples collected from the alluvial aquifer (approximately 28 percent) (Table 4-4). Detectable DMPT concentrations in alluvial aquifer groundwater ranged from 100 to 4,500,000 ug/l. The maximum DMPT concentration was detected in October 2006 in alluvial aquifer monitor well EC-09 located along

the northern boundary of the Stauffer Former Phosphoric Acid Pond and Leach Field.   As shown on Figure 4-39, DMPT in the alluvial aquifer extends beneath the proposed BRC CAMU towards the GWTS.   DMPT was also detected in the alluvial aquifer north of the Montrose Former Plant Site and Montrose Closed Ponds Area.   In general, DMPT concentrations decrease from the former facilities to the GWTS.   Although, an MCL for DMPT has not been established, the NDEP has approved (NDEP, 2007a) the Drinking Water Human Health Toxicity Criteria developed by Integral Consulting, Inc. (Integral, 2006) to address the five Organic Acids (including DMPT) which are a subset of the SRCs.   The Drinking Water Human Health Toxicity Criteria developed for DMPT is 3,700 ug/l.

The GWTS appears to be effective at controlling the migration of DMPT in the alluvial aquifer groundwater as demonstrated by the significant reduction in concentration across the wellfield (Figure 4-39).   The sole location where DMPT exceeds 3,700 ug/l in alluvial aquifer groundwater downgradient of the GWTS is at monitor well MW-R which produced groundwater with a concentration of 4,400 ug/l.

Fine-Grained Upper Muddy Creek Formation

DMPT was detected in groundwater samples collected from the UMCf at the Site (Figure 4-6A). DMPT was detected above laboratory MRLs in five of the 31 groundwater samples from the UMCf that have been analyzed for this compound (approximately 16 percent) (Table 4-5). Detectable DMPT concentrations in the five groundwater samples of UMCf groundwater with detectable concentrations ranging from 290 to a maximum concentration of 2,800 ug/l at UMCf monitor well MC-MW-09.   Figure 4-6A, which includes analytical results for samples collected from UMCf wells for the most recent period prior to the preparation of the figure indicates DMPT was only detected in well MC-MW-10 above the laboratory MRL at a concentration of 290 ug/l, but was not detected above the laboratory MRL of 250 ug/l in the most recent groundwater sample from MC-MW-09.

Coarse-Grained Upper Muddy Creek Formation

DMPT has not been detected above laboratory MRLs in the UMCc.

4.3.20 <u>Arsenic in Soil and Groundwater</u>

Arsenic is a naturally occurring metal in soil at the Site. A maximum provisional background concentration of 7.2 mg/kg has been proposed by Timet and BRC based on a background study (Section 4.1). This maximum provisional background concentration is greater than the arsenic Industrial PRG of 1.59 mg/kg. The distribution of arsenic in soil and groundwater is described below. Chemical cross-sections depicting the vertical distribution of arsenic in the subsurface are included in Appendix D, Figures D-17A and D-17B.

4.3.20.1 Arsenic in Surface Soil

Arsenic was detected above laboratory MRLs in all 41 surface soil samples (Table 4-1 and Figure 4-40). Detectable arsenic concentrations in surface soil ranged from 0.85 to 4.9 mg/kg. Arsenic was detected in 35 surface soil samples above the Industrial PRG (approximately 85 percent of the total number of samples), but less than the maximum provisional background concentration in all cases. The maximum arsenic concentration detected in surface soil was from boring FTF-14S located in the Montrose Former Tank Farm.

4.3.20.2 Arsenic in Vadose Zone Soil

Arsenic was detected above laboratory MRLs in 206 of the 207 vadose zone soil samples (approximately 100 percent) (Table 4-2 and Figure 4-40). Detectable arsenic concentrations in vadose zone soil ranged from 0.35 to 25 mg/kg. The maximum arsenic concentration in vadose zone soil was detected at a depth of 30 feet bgs in boring FPS-02D in the Montrose Former Plant Site.   The maximum concentration is greater than the arsenic Industrial PRG and maximum provisional background concentration.   Arsenic was detected in 193 samples at concentrations greater than the Industrial PRG (approximately 93 percent of the total number of samples). Arsenic was detected in 43 samples at concentrations greater than the maximum provisional background concentration (24 percent).   In general, the highest arsenic concentrations were detected at depths greater than 30 feet, where the vadose zone soil tends to be a fine-grained mixture of alluvial and UMCf sediments.

All but one of the 43 exceedances of the maximum provisional background concentration were reported in samples collected at depths greater than 10 feet, which was the maximum depth sampled in the background study. Therefore, the maximum provisional background concentration may not be representative of deeper soil at the Site. The Companies understand that Timet and BRC are in the process of performing a background study for arsenic in deeper soil (Timet, 2007a). Additional evaluation of the arsenic concentrations at the Site may be performed after the result of this study are available.

4.3.20.3 Arsenic in Saturated Zone Soil

Arsenic was detected above laboratory MRLs in the eight saturated zone soil samples (Table 4-3, Figure 4-4, and Appendix D, Tables D-24). Detectable arsenic concentrations in saturated zone soil ranged from 3.2 to 25 mg/kg. The maximum concentration of arsenic in saturated zone soil was detected at a depth of 85 feet bgs in monitor well MC-MW-10 located approximately 800 feet north of the Montrose Former Plant Site.

4.3.20.4 Arsenic in Groundwater

Alluvial Aquifer

The distribution of arsenic in alluvial aquifer groundwater is shown in Figure 4-41. Arsenic is a naturally occurring metal in alluvial aquifer groundwater in the vicinity of the Site. Arsenic was detected above laboratory MRLs in 162 of the 168 groundwater analyses from the alluvial aquifer (approximately 96 percent) (Figure 4-41). Detectable arsenic concentrations in alluvial aquifer groundwater ranged from 9.4 to 2,700 ug/l. The maximum arsenic concentration was detected in October 2006 in alluvial aquifer monitor well AA-MW-13 located approximately 300 feet west of the Montrose Former Plant Site. The maximum concentration is greater than the MCL for arsenic of 10 ug/l. Arsenic was detected in 161 samples above the MCL (approximately 96 percent of the total number of samples).

Arsenic was detected above the MCL in the alluvial aquifer over large portions of the former facilities, beneath the proposed BRC CAMU, near the GWTS, and in the downgradient area

(Figure 4-41). The highest arsenic concentrations were detected in the south central portion of the Pioneer property. In general, arsenic concentrations decrease from the former facilities in the southern portion of the onsite area to the downgradient area.

Fine-Grained Upper Muddy Creek Formation

Arsenic was detected above laboratory MRLs in 29 of the 31 groundwater analyses from the UMCf (approximately 94 percent) (Table 4-5 and Figure 4-6A). Detectable arsenic concentrations in UMCf groundwater ranged from 9.6 to 260 ug/l. The maximum arsenic concentration was detected in March 2007 in UMCf monitor well MCF-BW-09B (screened from 58 to 78 feet bgs) located along the southern boundary of the proposed BRC CAMU. The maximum concentration is greater than the MCL. Arsenic was detected in 27 samples above the MCL (approximately 87 percent of the total number of samples). Arsenic may be naturally occurring in the UMCf groundwater.

Arsenic was detected in the UMCf in all monitor wells at concentrations above the MCL (Figure 4-6A).

Coarse-Grained Upper Muddy Creek Formation

Arsenic was detected above laboratory MRLs in all 16 groundwater analyses from the UMCc (Table 4-6 and Figure 4-6B). Detectable arsenic concentrations in UMCc groundwater ranged from 15 to 160 ug/l. The maximum arsenic concentration was detected in October 2006 in UMCc monitor well MW-08 located approximately 900 feet north of the Montrose Former Plant Site. All 16 arsenic detections were above the MCL. Detectable arsenic concentrations ranging from 15 to 42 ug/l have been detected in Tronox UMCc monitor wells TR-01, TR-03, TR-05, and TR-11 over the period December 2006 to April 2007. Arsenic may be naturally occurring in the UMCc groundwater.

4.3.21 Total Dissolved Solids in Groundwater

Groundwater in the alluvial aquifer and Muddy Creek Formation in the vicinity of the Site has a naturally occurring concentration of TDS.   Background studies to determine the naturally occurring TDS concentration have not been performed.   The distribution of TDS in groundwater is described below.

Alluvial Aquifer

The distribution of TDS in alluvial aquifer groundwater is shown in Figure 4-42.   Based on 175 analyses, detectable TDS concentrations ranged from 700 to 60,000 mg/l in the alluvial aquifer (Table 4-4 and Figure 4-42).   The maximum TDS concentration in the alluvial aquifer was detected in October 2006 in monitor well EC-01.

The highest TDS concentrations are observed in three areas: 1) north of the Former Phosphoric Acid Pond and Leach Field, 2) the south central portion of the Pioneer property, and 3) north of the CAPD Pond 2.   TDS concentrations upgradient of the former facilities are generally lower than those detected throughout the former facilities.   In general, TDS concentrations decrease from the former facilities in the southern portion of the onsite area to the downgradient area.   The extent of elevated TDS concentrations relative to upgradient of the former facilities (as delineated by monitor well H-13 with a TDS concentration of 1,300 mg/l) is uncertain immediately east of the eastern Pioneer property boundary.

Fine-Grained Upper Muddy Creek Formation

Detectable TDS concentrations ranged from 620 to 31,000 mg/l in the UMCf based on 31 analyses (Table 4-5 and Figure 4-6A).   The maximum TDS concentration in the UMCf was detected in October 2006 in MCF-BW-09B.   TDS concentrations reported in the UMCf are generally less than those reported in the alluvial aquifer.

Coarse-Grained Upper Muddy Creek Formation

Detectable TDS concentrations ranged from 640 to 790 mg/l in the UMCc based on 16 samples (Table 4-6 and Figure 4-6B). The maximum TDS concentration in the UMCc was detected in December 2006 in monitor well TR-05.

4.4 NON-AQUEOUS PHASE LIQUIDS

4.4.1 Lines of Evidence

Defining the location and extent of NAPL is always difficult. This difficulty is attributable to the way NAPL may move through the vadose zone and groundwater (Section 5.2) and due to its physical characteristics such as low solubility in water and specific gravity differences from water (Section 5.4.1.4). These same factors result in difficulties in managing a dissolved-phase plume resulting from NAPL sources.

Current and previous EPA guidance regarding defining the existence and extent of NAPL indicate that it is best to use a "preponderance of evidence" approach. This approach includes review of several lines of direct and indirect evidence to define the most likely areas where NAPL may exist in the subsurface.

Direct Evidence

Direct evidence can be used to delineate areas where residual NAPL is present in the soil column or aquifer matrix or where floating LNAPL or pooled DNAPL may exist. An example of direct evidence is a positive finding when a NAPL-reactive fabric (such as a FLUTe® ribbon) is directly applied to a subsurface core. Such direct visual evidence not only provides information regarding the presence of NAPL, but also provides evidence of the type of DNAPL present (i.e., residual or disseminated DNAPL in the soil or aquifer matrix). An additional line of direct evidence is free phase liquid collected in specially-designed DNAPL collection sumps placed in the monitor well or based on encountering LNAPL above the water surface in wells screened above the water table. Encountering free phase liquid can indicate the presence of floating LNAPL or pooled DNAPL at the well location where the sample was collected. Finally, NAPL

can be visually identified by field geologists in cases when intact core samples of subsurface sediments are brought to the surface.

Indirect Evidence

Indirect evidence cannot be used to conclusively indicate the presence of a NAPL, but can indicate the potential presence of NAPL. Indirect evidence is therefore only used as corroborative evidence of NAPL and should be evaluated carefully and qualified if direct evidence is not observed. Each type of indirect evidence has its value, and weakness, for determining the presence of NAPL.

A positive finding using a NAPL probe provides only evidence of fluids of different specific gravity or density (actually optical properties that result from different specific gravity/density) but does not provide any indication of the chemical makeup of the fluid. This is particularly true in cases when the NAPL probe appears to indicate a positive finding in a monitor well collection sump. Other liquids, such as brines, can also collect in the sump and brines also have different optical properties than typical groundwater. Differentiating brines from DNAPL requires running a suite of laboratory chemical analyses. Therefore, the NAPL probe evidence cannot be used by itself to identify a DNAPL.

Elevated concentrations of NAPL-forming chemicals detected in soil gas or groundwater by chemical analysis or PID/FID measurements are typically viewed as good corroborative evidence of the presence of DNAPL. Presence of dissolved phase organics in groundwater samples at concentrations that approach the solubility limit, or a large percentage of the solubility limit, are given the most weight as evidence. The type of NAPL that may be present (DNAPL or LNAPL) is then based on the specific gravity of the particular organic compound.

The presence of high concentrations of dissolved phase organics can only indicate that a NAPL source possibly exists nearby in the soil gas or upgradient in the groundwater. However, the presence of high concentrations of organic compounds in groundwater at a particular location can be explained in other ways. Organic vapors in soil gas and dissolved phase organics in groundwater, even at highly elevated concentrations, can migrate with the soil gas or groundwater for significant distances. Additionally, elevated concentrations of organic compounds in soil gas or groundwater may be residual associated by a historical LNAPL or

DNAPL source that no longer exists today. This type of indirect evidence does not provide information on the type of NAPL (residual or pooled) that may exist, or previously existed, near the sample location. Likewise, the presence of elevated organic vapors does not provide sufficient evidence to determine if the odors are related to organic compounds in a NAPL or dissolved in groundwater or soil moisture.

Preponderance of Evidence

Thus, all of the evidence must be viewed together to estimate the area where LNAPL or DNAPL may likely exist at the Site. The direct evidence must be weighed more heavily to develop any estimate of the location and extent of NAPL

In summary, the data that can provide direct evidence of NAPL include visual identification of NAPL-like substances in the soil or aquifer matrix in core collected at the site, reaction to FLUTe® ribbon applied to the core, and the collection of samples of free phase or dense fluids from monitor wells. The data that provide indirect evidence of NAPL include:

- Detection of fluids of different specific gravity or density (actually optical properties that result from different specific gravity/density) in monitor wells using a NAPL probe;
- Elevated concentrations of volatile or semi-volatile organic compounds detected in soil gas samples or groundwater, and
- Detection of elevated concentrations of organic vapors using a PID and/or a FID to screen drill cuttings and cores and detection of organic odors during drilling operations.

4.4.2 Scope of NAPL Investigations

As described in the Supplemental Groundwater Investigation Work Plan (H+A, 2006c), several types of data have been collected to investigate the potential for NAPL at the Site. Activities to assess for the potential presence of NAPL, including both LNAPL and DNAPL, at source areas are summarized in Table 4-9. These activities at potential source areas associated with former Stauffer operations have included: 1) completion and visual examination of fourteen continuous core soil borings throughout the vadose zone; 2) field screening the continuous soil core using a PID and FLUTe® ribbon fabric; 3) constructing groundwater monitor wells appropriately designed to assess the presence of NAPL, including placing the top of the well screen interval above the water table in order to detect potential LNAPL and completing the wells with a one- to

three-foot long bottom sump in order to detect potential DNAPL; and 4) measuring groundwater monitor wells for the presence of NAPL using a product/water interface probe.

All alluvial aquifer monitor wells installed by Montrose and SMC/Syngenta beginning in 2006 were designed to assess the presence of NAPL, including placing the top of the well screen interval above the water table and completing the wells with a one- to three-foot long bottom sump (Table 4-10). Deeper monitor wells completed in the UMC also include a one- to three-foot long bottom sump. Although several of these new monitor wells were included in the Phase I and II sampling events, not all pre-existing monitor wells included these design features.

4.4.3 Findings

Data collected during the drilling of DNAPL reconnaissance borings, soil borings and monitor wells have produced evidence of the existence of DNAPL at the Site in the Alluvial Aquifer and UMCf (Table 4-9). However, there has been no evidence to suggest that LNAPL is present in either of these units. To date, no direct or indirect evidence suggest that NAOL is present in the UMCc.

As summarized in Table 4-9, while elevated PID measurements were encountered in several of the soil borings, no direct evidence for the presence of NAPL was observed in the continuous soil cores based on visual observations and screening with the FLUTe® ribbon fabric. Additionally, NAPL has not been detected using a product/water interface probe in any of the groundwater monitor wells measured during the Phase I and Phase II Site-Wide Groundwater Sampling Events or ongoing site-wide Groundwater Monitoring Program.

Composite maps have been prepared that present the forms of direct and indirect evidence of DNAPL collected at the Site for the Alluvial Aquifer and UMCf (Figures 4-43 and 4-44). The composite maps for each of these units include inset maps of direct evidence and indirect evidence

The direct evidence maps include a map of visual identification of NAPL. The indirect evidence maps include a map of FID readings and a map of percent solubility. The groundwater concentration data from the groundwater plume maps were used to calculate percent solubility

for each of the organic compounds that are known to form LNAPL or DNAPL and that have been detected at concentrations exceeding 5% of their water solubility. Those chemicals that were detected in groundwater samples at concentrations equal to or greater than 5% of their solubility (Table 4-8) include: benzene, chlorobenzene, 1,2-dichlorobenzene, 1,4-dichlorobenzene and chloroform. For each monitor well, the maximum percent solubility of any of these compounds was used to prepare the "Percent Solubility" map.

4.4.4 Interpretation and On-Going Investigations

The larger map displayed on Figure 4-43 and 4-44 outlines the area where the preponderance of evidence indicates that DNAPL is likely present in either residual form in the aquifer matrix or potentially pooled NAPL. The DNAPL observed in the vicinity of the former Montrose facilities was encountered as a residual mass (i.e., not pooled) between 30 and 120 bgs over this area. The shallowest occurrences of DNAPL were observed in reconnaissance boring RB-03 located in the northwest portion of the Montrose Former Plant Site. Additional investigations are ongoing to further delineate the occurrence of DNAPL.

The presence of NAPL in groundwater will continue to be evaluated using a product/water interface probe during groundwater monitoring and sampling activities to be conducted as part of future monitoring programs and through collection and chemical analysis of fluids found in monitor well collection sumps. In addition, indirect methods for assessing the potential presence of NAPLs (i.e., comparison of dissolved chemical concentrations to aqueous solubility limits as listed in Table 4-8) will be considered to focus the scope of future data collection activities.

5.0 TRANSPORT MECHANISMS

Potential contaminant transport pathways within the CSM study area include air, soil, surface water, and groundwater. Each pathway and potential transport mechanisms are discussed in the following sections.

5.1 AIR PATHWAY

Contaminant transport can occur through the air pathway via two mechanisms: 1) windborne particulates, and 2) volatilization of contaminants into ambient air. Windborne particulate transport can occur when contaminated surface soils are present and particulates are mobilized and carried by wind. This pathway and mechanism can also transport contaminants from subsurface soils if they are excavated or grading exposes them to the effects of wind. The second mechanism by which contaminants can be transported via the air pathway is the migration of volatile compounds through soil pore space.

Surface soil samples (i.e., less than 1 foot bgs) and shallow soil samples (i.e., less than 2 ft bgs) have been collected from most potential source areas at the former Montrose and Stauffer facilities. The samples have been analyzed for selected SRCs or the full SRCs list based on the facility location and date of sampling (H+A, 2005a; PES, 2007a and 2007b). The results of these sampling activities are described in Section 4.0.

Transport of windborne particulates is a contaminant transport mechanism. A risk assessment workplan was recently submitted for Stauffer (Integral, 2008) that includes an evaluation of exposure to windblown particulates, including the SRC of asbestos. A tiered modeling approach is proposed to evaluate windborne particulates generated by wind erosion and construction activities. Many of the potential source areas have been capped with clay and/or asphalt and are therefore likely to have negligible windborne emissions. Stauffer and Montrose facilities that have been capped include:

- Asphalt Cover: Former ACD Plant, Former Lindane Plant, and Former BHC Cake Piles 1 and 2.

- Soil/Clay Cover: Stauffer BHC Cake Pile 3, ACD Drum Burial Waste Management Area, and the Former Leach Field and Phosphoric Acid Pond/Trenches; and Montrose Closed Ponds Area and Former Plant Site.

The second mechanism via the air pathway is the migration of volatile compounds through soil pore space. These vapors can migrate into the atmosphere or can be transported deeper into the ground and potentially impact groundwater, depending primarily on volatility of the compound, and also on molecular weight, the carbon content (fraction organic carbon [f_{oc}]) and physical properties of the soil matrix (porosity, grain size distribution, and moisture content) and temperature gradients.

The volatility of a chemical compound increases as its vapor pressure increases. Vapor pressures greater than 1 mm of mercury are considered highly volatile, vapor pressures in the range of 0.001 to 0.1 mm of mercury are considered semi-volatile and vapor pressures less than 0.001 mm of mercury are non-volatile under normal conditions. Due to the high summer temperatures at the Site, the volatile and semi-volatile compounds in the surface or near surface are susceptible to being volatized and released to the atmosphere. This process of near surface volatilization is probably complete because the operations that resulted in the release of SRCs to the subsurface ceased over 20 years ago.

VOCs and SVOCs dissolved in soil moisture and groundwater can also volatilize and be released to the atmosphere via soil gas respiration. The potential for these compounds to volatilize from the vadose zone soil moisture and groundwater is defined by the Henry's Law Constant (K_H) for that compound. K_H provides a measure of the extent of chemical partitioning between air and water at equilibrium. The higher the K_H the more likely a chemical is to volatilize than to remain in water. A K_H exceeding 10^{-3} atmospheres-cubic meters per mole (atm-m^3/mole) indicates a compound that is readily volatilized from a dilute aqueous solution. Compounds that have a K_H of less than 10^{-7} atm-m^3/mol are considered to have a low volatility.

The potential volatility of the Site chemicals range from non-volatile to highly volatile based on their vapor pressure and K_H (Table 4-8). These data indicate that the SRCs benzene, chlorobenzene, 1,2-DCB and 1,4-DCB, 1,2,4-TCB, PCE, carbon tetrachloride, and chloroform are volatile and that there is a potential for these compounds to be transported as vapor to the atmosphere. In contrast, the SRCs that are pesticides including 4,4'-DDE, 4,4'-DDT,

alpha-BHC, beta-BHC, gamma-BHC, and carbophenothion have low vapor pressures and K_H, so there is little potential for these compounds to be transported as vapors via the air pathway.

Limited air monitoring has been performed at the former Montrose and Stauffer facilities. Breathing space air monitoring during drilling activities and groundwater sampling activities conducted at the Site have not detected significant concentrations of volatile compounds (Appendix B). In addition, shallow soil gas sampling and shallow soil sampling indicate that volatilization and transport of contaminants in air from the shallow soil and/or groundwater, although possible, is not likely a significant transport pathway at the Site as shallow soil gas sampling results do not indicate significant concentrations of VOCs in the shallow soil (Appendix B).

Pioneer conducted an ambient air monitoring study in the onsite area in 2002 (CTEH, 2002). The objective of the study was to determine if former Montrose operations area and Stauffer operational and waste disposal areas were sources of odors reported by Pioneer workers. The results suggested that the former Montrose and Stauffer facilities were not a source of these odors reported by Pioneer workers (Section 4.2).

5.2 SOIL PATHWAY

Contaminants may be transported in soil by several mechanisms including vapor transport, dissolved-phase transport in soil moisture, NAPL migration from sources to the soil and/or groundwater, and co-solvency.

There is also a potential for transport of contaminants in the subsurface soil to groundwater via migration in the vadose zone. Contaminant migration from soils to groundwater is largely a function of solubility and partitioning coefficients of the contaminant and the properties of the soil including texture and organic composition. The potential for transport in subsurface soil is controlled by the nature of the release to the soil, the physical properties of the soil, and the contaminant's ability to adsorb to the soil matrix or dissolve in the soil moisture. The ability of a compound to adsorb to organic matter contained in the soil relative to dissolution in soil moisture in the vadose zone, or in groundwater, is described by the Octanol-water coefficient (K_{ow} or $\log(K_{ow})$) for the compound. Compounds with high K_{ow} values have a greater tendency

to adsorb to carbon in the soil matrix, whereas compounds with low K_{ow} values are more likely to partition to the soil moisture or groundwater.

The amount of organic matter in the soil matrix is described by the f_{oc}. Soil with little to no organic carbon, or low f_{oc}, does not provide an opportunity for compounds to adsorb to the matrix, whereas soils with high f_{oc}, provide an opportunity for compounds to readily adsorb to the matrix.

Data on the K_{ow} values for the SRCs can be obtained from literature, but the f_{oc} values for the soil matrix must be obtained by analyzing soil samples (Table 4-8). Estimates of f_{oc} can be made for the Qal deposits comprising the vadose zone at the Site using total organic carbon analyses of soil samples collected from soil borings SB-EC-01 through SB-EC-14 (PES, 2007a and Figure 3-12). A total of 56 soil samples were collected from these 14 soil borings at depths ranging from land surface to a depth of 49 feet bgs and analyzed for total organic carbon. Review of the analytical results from these soil samples indicates that the total organic carbon content of the soil samples ranges from 550 mg/kg to 44,900 mg/kg (PES, 2007a). A conversion from mg/kg to grams per gram to get the f_{oc} values in percent yield f_{oc} values that range from 0.055 to 4.0 (Table 5-1). Existing data indicate that 45 of the 56 samples have f_{oc} values less than 0.5 percent. These data indicate that the Qal deposits comprising the vadose zone at the Site generally has a low organic carbon content, which will lessen the propensity for adsorption of SRCs compared to high organic carbon soil.

The VOCs benzene, chlorobenzene, chloroform, and carbon tetrachloride have relatively low K_{ow} values and are expected to be more mobile in the subsurface. The pesticides (isomers of BHC, DDE, and DDT) have relatively high K_{ow} values and typically are relatively immobile in the subsurface. However, the f_{oc} values available for Site soil are low. The occurrence of low f_{oc} values within the vadose zone and detections of pesticides in groundwater beneath and downgradient of the potential source areas, indicates that these compounds have migrated through the vadose zone to groundwater and that migration of pesticides may be facilitated by the presence of other organic chemicals.

In addition to vapor transport and migration via infiltration, contaminants can also be transported in soil via NAPL migration. The following description of NAPL fate and transport is from Kueper, et al., 2003:

There are two types of NAPL. Light Non-aqueous Phase Liquids (LNAPL) are less dense than water and Dense Non-aqueous Phase Liquids (DNAPL) are more dense than water. LNAPLs that reach the water table typically pool on the water table (float), whereas DNAPLs penetrate the water table (sink). NAPLs are only slightly soluble in water and therefore exist in the subsurface as a separate fluid phase immiscible with both water and air. Unlike LNAPLs such as fuel hydrocarbons and heating oil, DNAPLs can migrate to significant depths below the water table where they slowly dissolve into flowing groundwater, giving rise to aqueous phase plumes. A release of DNAPL at the ground surface can therefore lead to long-term contamination of both the unsaturated and saturated zones at a Site.

In unsaturated porous media, DNAPL forms discrete blobs and ganglia of liquid that are disconnected from each other. The DNAPL blobs are exposed to both air and water, allowing for both vaporization into the air phase across DNAPL-air interfaces and dissolution into infiltrating water across DNAPL-water interfaces. Once present in soil moisture, dissolved contaminants will be available for partitioning across air-water interfaces (a process referred to as volatilization). Because the vapour pressure of many DNAPL compounds is relatively high, the lifespan of residual DNAPL in the unsaturated zone can be much less than the lifespan of residual DNAPL below the water table. The vaporization process can deplete residual chlorinated solvent DNAPLs such as TCE and PCE within 5-10 years in relatively warm and dry climates. This will not eliminate the presence of vapour phase, absorbed phase and aqueous phase contamination in the unsaturated zone, but it can lead to an absence of the DNAPL phase. The absence of DNAPL in the unsaturated zone at a site does not, in general, mean that past releases of DNAPL did not occur at that site or that past releases of DNAPL failed to reach the water table.

DNAPL released in unconsolidated deposits can also come to rest in larger accumulations referred to as pools. DNAPL pools tend to form above finer grained horizons that provide the necessary capillary resistance to support the DNAPL accumulation. Unlike residual DNAPL, pools contain DNAPL that is

continuous between adjacent pores, with local saturations of up to approximately 70 percent of the pore space. The finer grained horizon upon which DNAPL pooling can occur need not be a well-defined, laterally extensive clay unit. DNAPL pooling can occur on silt and fine sand horizons at all elevations within unconsolidated deposits. The maximum pool height is inversely proportional to the permeability of the particular horizon upon which pooling is taking place, with clay and silt units typically supporting higher pools than fine sand horizons.

Residual and pooled DNAPL collectively form what is referred to as the DNAPL source zone. It is within the DNAPL source zone that dissolution into groundwater occurs and aqueous phase plumes originate. DNAPL will not migrate downwards through unconsolidated media as a uniform body, but instead will migrate along multiple pathways in a very tortuous manner; this is sometimes referred to as dendritic form due it its resemblance to the branches of a tree. The specific migration pathways will be governed by the bedding structure of the porous medium, with migration occurring along pathways on the scale of millimeters to meters. In horizontally bedded media, significant amounts of lateral spreading can be expected, including in directions not coincident with the direction of groundwater flow. The field experiments reported by Poulsen and Kueper (1992), and Kueper et al. (1993) demonstrated, for example, that the orientation of bedding structures is the primary factor controlling the directions and specific pathways of DNAPL migration.

These experiments also demonstrated that slow, dripping releases of DNAPL are likely to migrate to greater depths than sudden, single event releases. It is, therefore, not practicable to define all of the specific DNAPL migration pathways at a typical industrial Site. A much more attainable, yet still difficult, goal is to define the lateral extent of the DNAPL source zone, without specific delineation of residual DNAPL and DNAPL pools within the overall source zone. Given the selective and tortuous nature of DNAPL migration, it follows that the majority of porous media within a DNAPL source zone will contain neither residual nor pooled DNAPL. The probability of directly encountering residual or pooled DNAPL with a conventional drilling program is therefore relatively small. It is now commonly accepted that direct visual observation of DNAPL does not occur at

most DNAPL sites. Instead, the presence of DNAPL is inferred using alternative lines of evidence. The overall bulk retention capacity of porous media within a DNAPL source zone is generally thought to range from approximately 0.5 to 3 per cent. This retention capacity is defined as the volume of DNAPL (as both residual DNAPL and pools) divided by the overall bulk volume of the source zone. These values are lower than local-scale residual saturations (5-20 percent of the pore space) because they are expressed in relation to the bulk volume impacted and because not all lenses and laminations within the impacted zone will have been invaded by the DNAPL. Exceptions will occur at some sites, with some source zones containing bedding structures and capillary properties capable of retaining higher amounts. Lower DNAPL density, higher DNAPL viscosity, and higher DNAPL-water interfacial tension generally lead to larger amounts of lateral DNAPL spreading both above and below the water table. Creosote, for example, has been observed to have migrated hundreds of meters from release locations at certain sites in the USA. The extent of lateral migration of chlorinated solvent DNAPLs tends to be less, but has been observed to be tens to hundreds of meters at many sites. This had led to a useful rule of thumb that in horizontally bedded media, 'DNAPL must migrate sideways in order to migrate down'.

The above excerpt is consistent with the occurrence of DNAPL beneath and/or north-northeast of the former Montrose facilities (Section 4.4).

Generally, co-solvents reduce the surface tension between a low solubility material and water suggesting an increase in the low solubility materials sorption into water. Laboratory studies indicate that in the presence of the co-solvent ethanol (volume fraction of 10 percent the aqueous solubility of benzene is increased by 20 percent. These studies also comment that co-solvency of BTEX compounds (benzene, toluene, ethylbenzene, and xylenes) is significant for aqueous concentrations of ethanol greater than 10 percent. The organic content of the soil found at the site ranges between 0.05 and 4 percent (the majority of soil samples indicated an organic content less than 0.5 percent). Considering all of the organic content in the soil as a potential co-solvent source, co-solvency is most likely not a significant factor in SRC migration.

5.3 <u>SURFACE WATER AND SEDIMENT PATHWAY</u>

Contaminants can also be transported via surface water runoff during precipitation events or if wastewater is released accidentally to land surface. Contaminants can be transported as dissolved phase in the surface water runoff or adsorbed onto the sediment load in the runoff. Soluble contaminants can be dissolved and transported across the land surface and/or infiltrate into the subsurface, contaminating the vadose zone and potentially migrating to the groundwater. Surface water can also concentrate and deposit-dissolved contaminants through evaporation when runoff pools in topographic low areas after precipitation events.

Onsite and offsite surface water and drainage conditions have been summarized in Section 2.0. Limited sediment sampling has been conducted in the Las Vegas Wash area outside of the CSM study area.

5.3.1 <u>Transport of Site-Related Chemicals with Surface Water Runoff</u>

SRCs were conveyed off of the former facilities historically in a series of unlined ditches (Weston, 1993). Soil sampling indicates that detectable concentrations of pesticides and benzene compounds were found in the vicinity of the ditches as a result of historical wastewater disposal and stormwater management. In December 1976, the BMI Complex became a "zero discharge" industrial effluent facility under NPDES resulting in the discontinuance of the use of the ditch conveyances (Section 2.1.7). Stormwater originating upgradient of the Pioneer property is diverted around the former facilities and onsite stormwater is collected and conveyed to onsite ponds.

5.4 <u>GROUNDWATER PATHWAY</u>

Contaminants such as organic compounds, inorganic compounds, and chlorinated hydrocarbons and certain pesticides are to varying degrees soluble in water and, therefore, can be transported from sources to environmental receptors via groundwater pathways. During groundwater transport, various natural processes act to modify the rate of transport and concentration of these compounds. Transport processes include advection, dispersion (including dilution), and diffusion. There are also various physical, chemical, and biological mechanisms that act to retard the rate of groundwater transport. These fate mechanisms

include volatilization, sorption, chemical alteration, and biodegradation. Additionally, mass removal of these contaminants may occur as a result of pumping or various remedial activities along the transport pathway.

This section discusses transport and fate mechanisms affecting the distribution of commonly detected SRCs in Site and CSM study area groundwater.

5.4.1 Transport of Site-Related Chemicals in Groundwater

The following sections briefly discuss monitoring data compiled by others that are relevant to the CSM.

5.4.1.1 Advection

Advection is the primary transport mechanism in the CSM study area. As dissolved components of flowing groundwater, SRCs are transported in the direction of groundwater flow by advection. Advective transport occurs because the organic and inorganic compounds are present in an aqueous component of the flowing groundwater. The rate of advective transport is proportional to the velocity of groundwater flow as well as the concentration of the solute (Fetter, 1999).

Advection is also a primary transport mechanism for colloidal particles present in the groundwater. Certain SRCs may preferentially sorb to colloidal particles, depending on colloidal composition. In groundwater systems where velocity is relatively high (near groundwater extraction and injection points), colloidal phase transport of compounds may be significant.

Horizontal advective transport of SRCs in alluvial aquifer groundwater is generally from the source areas in the southern portion of the Site to the north toward the groundwater extraction well field. Treated groundwater from the well field is recharged downgradient of the well field where a portion of it migrates towards Las Vegas Wash. Since the vertical groundwater flow is generally upward from the UMCf and UMCc to the alluvial aquifer (Section 3.0), advective transport of SRCs from impacted zones within the UMCf to the alluvial aquifer is likely to occur at the Site in areas where upward gradients persist.

Advective (conservative, non-retarded) solute transport rates have been estimated for the alluvial aquifer and the Muddy Creek Formation within the CSM study area using the following equation:

$$v_x = \frac{K}{n} \frac{\partial h}{\partial l}$$

Where:

v_x = average linear velocity of groundwater flowing in the x direction [length(L)/time(T)]

K = saturated hydraulic conductivity of the porous medium [L/T]

n = effective porosity of the porous medium

$\partial h/\partial l$ = hydraulic gradient (difference in head (h) over transport distance (l)) [L/L]

Average hydraulic conductivities for the alluvial aquifer and UMCf of 75 ft/d and 0.05 ft/d, respectively, were assumed based on limited aquifer test data (Section 3.5). A hydraulic gradient of 0.015 was estimated based on Site data and assumed to be representative of the alluvial aquifer and UMCf. Effective porosities of 0.3 and 0.4 were assumed for the alluvial aquifer and UMCf respectively, based on literature values for lithologies (Fetter, 2001). Using these parameter estimates, the estimated average linear groundwater velocities at the Site are 1,400 and 0.7 feet per year the alluvial aquifer and UMCf, respectively.

5.4.1.2 Dispersion

Dispersion of dissolved chemicals occurs during advective transport of groundwater through a porous medium. The irregular and tortuous flow paths in the porous medium cause groundwater to move at variable velocities within the pore space. Thus, as dissolved chemicals are transported by advection, some fraction of the total dissolved mass moves faster than the average linear groundwater velocity and some fraction moves slower. This process, known as mechanical dispersion, is essentially the process of mixing of waters of various solute concentrations. Mechanical dispersion acts in all three aquifer dimensions (longitudinal, transverse, and vertical) to distribute or spread the solute across increasingly greater volumes of the aquifer than would be expected under normal "plug flow." At the same time, the concentration of solute may be reduced as the solute intermingles with fresh water (dilution).

5.4.1.3 Diffusion

Another physical mechanism that acts to distribute solute mass is diffusion, which results from the thermokinetic energy of the chemical molecules arising from chemical concentration gradients. Diffusion also acts to reduce the concentration of solute by spreading over a greater volume.   In most advection-dominated groundwater flow systems, the effect of diffusion is generally assumed to be much less that that of mechanical dispersion, and is, therefore, ignored. Diffusion is probably negligible in terms of its importance to compound solute transport in the CSM study area.

5.4.1.4 DNAPL Transport

DNAPL movement in the subsurface is controlled by the source variability, the viscosity, and density of the DNAPL materials and the physical properties of the porous media (Site unconsolidated soil).   As discussed previously, the following information on DNAPL fate and transport is summarized in Kueper, et al., 2003:

> Upon release at the ground surface, the DNAPL will migrate both vertically and laterally in the subsurface. Residual DNAPL, in the form of disconnected blobs and ganglia of organic liquid, is formed at the trailing end of a migrating DNAPL body. The formation of residual DNAPL, which occurs in response to pore-scale hydrodynamic instabilities, always takes place. The individual blobs and ganglia of organic liquid comprising residual DNAPL are typically between 1 and 10 grain diameters in length. Residual DNAPL will form in both unsaturated and saturated media, and is held in place by capillary forces that arise because the interface between the DNAPL and water, and the interface between DNAPL and air, is in a state of tension.
>
> The amount of residual DNAPL retained by a typical porous medium such as silt, sand and gravel is typically between 5 and 20 percent of the pore space in the particular lenses and laminations invaded by the DNAPL. The residual DNAPL forms discrete blobs and ganglia of liquid that are disconnected from each other. In most types of porous media, even relatively large hydraulic gradients cannot

mobilize residual DNAPL. Site investigation activities such as pumping tests and well purging will therefore not draw residual DNAPL into well screens and sand packs.

As discussed above in the soil pathway discussion (Section 5.2):

DNAPL will not migrate downwards through unconsolidated media as a uniform body, but instead will migrate along multiple pathways in a very tortuous manner; this is sometimes referred to as dendritic form due it its resemblance to the branches of a tree. The specific migration pathways will be governed by the bedding structure of the porous medium, with migration occurring along pathways on the scale of millimeters to meters. In horizontally bedded media, significant amounts of lateral spreading can be expected, including in directions not coincident with the direction of groundwater flow.

Impact of Physical and Chemical Characteristics on DNAPL Transport

The following description of DNAPL transport and the impacts of the physical and chemical characteristics of the DNAPL forming compounds and the characteristics of the porous media is taken from Appendix B of "Site Characterization Technologies for <u>DNAPL Investigations</u>" (EPA, 2004). In addition, if available, the physical/chemical characteristics of the predominant potential LNAPL and DNAPL forming compounds that have been identified in soil and groundwater are provided, or Table references are provided. The analysis of soil samples that exhibited evidence of residual DNAPL and samples of DNAPL collected from monitor wells at the site indicate that DNAPL at the Site is comprised of a mixture of organic compounds, and is predominantly a mix of five VOCs. The five predominant NAPL forming compounds include: Benzene, Chlorobenzene, 1,2- and 1,4- dichlorobenzene, and Chloroform. Other potential DNAPL forming compounds have been identified at the Site, but are not as prevalent and have not been found at concentrations that suggest DNAPL. Of the five compounds Chlorobenzene, 1,2- and 1,4- dichlorobenzene, and Chloroform typically form DNAPL while Benzene is not typically observed as a DNAPL. However, the DNAPL observed at the Site is a mixed DNAPL and Benzene is present in the mixture. Thus, the DNAPL observed at the Site likely exhibits different physical and chemical characteristics that any of the component compounds and may vary based on the relative mix of compounds at various depths and locations.

Dense, non-aqueous phase liquids (DNAPLs) are more dense than water and are relatively immiscible in water, allowing them to remain in a non-aqueous phase. While these are defining features of DNAPLs, there are a number of other physical and chemical properties that influence actual migration in the subsurface and their physical/geochemical behavior. Their behavior is determined by complex interactions between the DNAPL chemicals and the hydrogeological formations through which the DNAPLs move. DNAPL chemicals are subject to the following processes:

- Downward migration by gravity;
- Absorption and adsorption on soil;
- Volatilization into soil gas;
- Dissolution and dispersion in groundwater;
- Preferential solution of components;
- Phase separation or the formation of emulsions, and
- Transformation into other chemicals by microbiological and/or chemical processes (when chemicals are in solution or air).

How these processes occur and to what degree they affect DNAPL migration are dependent on the chemical make up of the DNAPL and the subsurface soil properties. When DNAPLs are composed of multiple compounds with differing physical characteristics, the characteristics of the mixture will be different than those of the pure substances. For example, the physical characteristics of a mixture of methylene chloride and trichloroethene will have a density and viscosity that is determined by the relative volumes of each constituent in the mixture. Mixtures with high proportions of methylene chloride will be less dense and viscous than mixtures with higher proportions of trichloroethene. With the right constituents and relative proportions, it is possible that a mixture of DNAPL and light nonaqueous phase (LNAPL, specific gravity < 1) chemicals can have offsetting physical characteristics, resulting in a mass that neither floats nor sinks in water (EPA, 2004).

DNAPL Physical/Chemical Characteristics

The physical/chemical properties of a DNAPL mass most important to subsurface migration are specific gravity and dynamic viscosity. Factors, such as vapor pressure, Henry's Law constant,

and solubility in water, contribute to the dissolution of the DNAPL chemicals into dissolved or soil gas vapor phases where they may undergo biodegradation and chemical transformation (EPA, 2004).

Specific Gravity

As indicated above, specific gravity is a defining characteristic of DNAPLs, which have specific gravities greater than one. Given relatively equal viscosities, the greater the specific gravity, the greater the tendency of the substance to migrate under the influence of gravity through the subsurface. Provided there is sufficient mass to drive the movement, the DNAPL will continue to move downward through preferential pathways (i.e., coarser grained materials that provide less capillary resistance) until it meets a zone of low permeability where it will tend to pool or, if the zone has a dip, will move across the surface to lower areas (EPA, 2004). The specific gravity, or density, of the potential DNAPL forming compounds used, disposed of and detected in groundwater at the Site range from 1.0646 (chlorobenzene) to 1.4832 (chloroform) (Table 4-8).

Limited solubility is another defining characteristic of most DNAPLs. When an organic chemical comes in contact with water, some or all of the chemical will dissolve or partition into the water up to the solubility limit of the chemical. The portion not dissolved remains as a non-aqueous liquid. Solubility of the DNAPL forming compounds detected at the Site vary widely and range from 73.8 to 7,920 mg/l for 1,4-dichlorobenzene and chloroform, respectively (Table 4-8). Organic compounds are rarely found in groundwater at concentrations approaching their solubility limits, even when an organic liquid phase is present. Therefore, high concentrations of dissolved DNAPL chemicals in groundwater can be very strong indicators that DNAPL mass sources are present. However, this statement does not imply that only high concentrations are indicators of free-phase liquids. EPA has recommended that concentrations as low as one percent of solubility can be indicators of DNAPL presence (Cohen and Mercer, 1993). DNAPLs that are a mixture of many chemicals will have solubilities that reflect their relative concentrations in the mixture. These solubilities are typically lower than the solubilities published for the pure chemical. Concentrations of individual chemicals found at less than one percent of their solubility does not mean there can be no DNAPL present at the site (EPA, 2004).

Dynamic Viscosity and Kinematic Viscosity

Dynamic, or fluid, viscosity is a measure of a fluid's resistance to flow. Molecular cohesion, the tendency of a fluid to remain undispersed, is the main contributor to viscosity. With lower viscosity comes greater mobility and penetration of porous media. Dynamic viscosity provides an indication of the ease with which a compound (in its pure form) will flow. The mobility of the compound in pure form is inversely proportional to its dynamic viscosity. The dynamic viscosity of water is approximately 1.0 centipoise (cp). The dynamic viscosity values of the five predominant DNAPL forming compounds detected in groundwater at site are as follows: 0.6468 cp – benzene; 0.756 cp – chlorobenzene; 1.302 cp – 1,2-dichlorobenzene; 1.258 cp – 1,4,-dichlorbenzene; and 0.563 – chloroform (EPA, 1991).

The kinematic viscosity of a compound takes into account the density of the compound and provides an indication of the ease with which the compound (in its pure form) will percolate through the subsurface. The lower the kinematic viscosity of a compound, the greater will be its tendency to migrate in a downward direction. Kinematic viscosity is of particular importance with regard to the movement of DNAPLs in aquifers. The lower the kinematic viscosity of a DNAPL, the greater will be the ease with which the DNAPL will move downwards and penetrate the finer grained layers in the subsurface. The kinematic viscosity of water is approximately 1.0 centistokes (cs). The kinematic viscosity values of the five predominant DNAPL formers in Site groundwater are: 0.7379 cs – benzene; 0.683 cs – chlorobenzene; 0.997 cs – 1,2-dichlorobenzene; 1.008 cs – 1,4,-dichlorbenzene; and 0.379 cs – chloroform (EPA, 1991).

Vapor Pressure

Vapor pressure, often expressed in millimeters of mercury (mm Hg), is the pressure at a given temperature of a vapor in equilibrium with its liquid or solid form (note this is measured in a closed container). The higher a DNAPL's vapor pressure, the higher its soil gas concentration will be. The vapor pressure values of the DNAPL formers range from 0.7 to 198 mm Hg (Table 4-8). One factor that influences the vapor pressure of a DNAPL in the subsurface is temperature. Conditions such as DNAPL flow velocity may affect the ability for the DNAPL mass to reach equilibrium with its soil gas, and therefore prevent the DNAPL soil gas from reaching its equilibrium vapor pressure. Cohen and Mercer estimate that a soil gas

concentration of a volatile DNAPL of 100 to 1,000 ppm is a good indication of the presence of a DNAPL source (EPA, 2004).

Henry's Law Constant

Henry's law constant is sometimes referred to as the air-water partition coefficient. It is defined and often represented as the ratio of the partial pressure of a compound in air to the concentration of the compound in water at a given temperature under equilibrium conditions. It can be used to predict the tendency of dissolved DNAPL chemicals to remain in the dissolved state or to migrate into the soil gas. It is very useful in formulating the site conceptual model and in determining whether a soil gas survey would be practical for investigating a groundwater plume (EPA, 2004). Henry's Law Constant values for the potential DNAPL formers are listed in Table 4-8.

Soil and Groundwater Characteristics that Affect DNAPLs

Characteristics of the soil and groundwater also determine the fate and transport of a DNAPL. The following soil and groundwater qualities have the most significant influence on the fate of a DNAPL:

- Initial moisture content;
- Capillary pressure;
- Residual saturation C Interfacial tension;
- Relative permeability, and
- Groundwater flow velocity.

Initial Moisture Content

The initial moisture content of soil can affect the potential for retaining the DNAPL in soil pores. This is due to the wettability of the pore space. Wettability refers to the preferential coating of a solid surface by one fluid in a multiple fluid system. In general, though not always, in a DNAPL water system the water is the wetting agent and will preferentially coat the walls of the pore space. The effect of this coating is to have the water occupy both the surface areas of the pores and smaller pores in the porous media while relegating the DNAPL to the larger openings

(Cohen and Mercer 1993). When soils are relatively dry, the system is a DNAPL air system with the DNAPL becoming the wetting agent. Hence soil with a very low initial moisture content will tend to draw in and retain DNAPLs more than similar soils with a high initial moisture content. The subsurface vadose zone, however, is generally heterogeneous and moisture content is not uniform in it and rarely absent. This heterogeneous distribution of water in the subsurface makes prediction of where DNAPL will be the wetting agent and where it will not be the wetting agent difficult at best (EPA, 2004).

Interfacial Tension

According to Bear 1979, when a liquid is in contact with another substance (another liquid immiscible with the first, a gas, or solid) there is free interfacial energy present between them. The interfacial energy arises from the difference between the inward attraction of the molecules in the interior of each phase and those at the contact surface. Since a surface possessing free energy contracts if it can do so, the free interfacial energy manifests itself as an interfacial tension. Thus the interfacial tension for a pair of substances i and k is defined as the amount of work that must be performed to separate a unit area of i from k. Interfacial tension is related directly to the capillary pressure across a water-NAPL interface and is a factor in controlling wettability. As a result of interfacial tension, nonwetting DNAPLs may form globules in open water and water saturated media (EPA, 2004).

Residual Saturation

Residual saturation is the amount of DNAPL that is retained or trapped in soil pores relative to the maximum retention capacity of the soil and is measured as a percentage of total pore volume. The propensity of a chemical to be retained is a function of the media pore size distribution, wettability, fluid viscosity ratio, density ratio, interfacial tension, and hydraulic gradients (Cohen and Mercer, 1993). In the vadose zone, NAPL is retained as films, wetting pendular rings, wedges surrounding aqueous pendular rings, and as nonwetting blobs in pore throats in the presence of water. Residual NAPL in the saturated zone is immobilized by snap off and bypassing mechanisms. Snap off occurs in high aspect ratio pores where the pore body is much larger than the pore throat, which results in single droplets or blobs of residual NAPL. Bypassing is prevalent when wetting fluid flow disconnects the nonwetting fluid causing NAPL

ganglia to be trapped in clusters of large pores surrounded by smaller pores (Cohen and Mercer 1993) (EPA, 2004).

Relative Permeability

When two or more fluids exist in a system, they will compete for pore space. The result is the mobility of each is reduced. Relative permeability is the ratio of the effective permeability through a medium of a fluid at a given saturation, to its intrinsic permeability at the same saturation. As such it varies with saturation from 0 to 1 (Cohen and Mercer 1993). Relative permeability values are generally required for fate and transport numerical modeling of immiscible fluids. Relative permeability values are rarely available for site specific problems and are generally estimated from the literature (EPA, 2004).

Capillary Pressure

Capillary pressure is the tendency of a porous medium (soil) to draw in the wetting fluid and repel the nonwetting fluid. This is due to the dominant adhesive force between the wetting fluid and media solid surfaces. Capillary pressure is a function of interfacial tension, contact angle (between the fluid interfaces and the solid), and pore size. It increases with a decrease in the contact angle and the pore radius or with an increase in the interfacial tension. The higher the capillary pressure, the greater the tendency of the medium to draw in the wetting fluid. Capillary pressure is important in DNAPL transport because in most cases it greatly affects the ability of the nonwetting DNAPLs to enter soil pore space and forces them to flow through areas with lower capillary pressures. In saturated or capillary fringe areas the capillary pressure can be sufficiently large to form a capillary barrier that prevents DNAPL penetration unless large heads are developed. In a strictly air DNAPL system (no moisture present), which is very rare, the DNAPL would be pulled into the pore space (EPA, 2004).

Groundwater Velocity

Movement of the dissolved phase of DNAPL chemicals is a function of advection and dispersion. As the groundwater velocity increases, so does the potential for increased advection and dispersion of dissolved DNAPL chemicals in that volume. Groundwater velocities vary from less than 1 ft per year to thousands of ft per year. As groundwater velocities increase,

the rate of flow of water passing across the outer surface of the DNAPL mass increases. Thus, an increase in groundwater flow velocity causes the rates of dissolution and dispersion of the DNAPL chemicals to increase. Conversely, as groundwater flow velocity decreases, so do the rates of dissolution and dispersion of the DNAPL. It should be remembered, however, that if the DNAPL chemical has permeated a low permeability soil with relation to the rest of the aquifer (e.g., clay lenses) the dissolution and movement will be controlled by diffusion from the low permeability soil not the velocity of the water moving across it. The affect of groundwater flow and gradient on DNAPL movement in the subsurface is related to the specific gravity of the DNAPL and its viscosity. Dense chlorinated solvents will tend to move based on gravity and stratigraphy with little influence from groundwater factors. On the other hand, DNAPLs with specific gravities close to 1 (e.g., creosotes and coal tars) can have their direction of flow strongly influenced by high groundwater flow velocities and gradients. An example of this would be creosote entering the bottom of a gaining surface water body. In this case, the flow of the DNAPL is up (EPA, 2004).

DNAPL Movement in the Subsurface

The following discussion is taken directly from Wolfe et al. 1997 and is provided because it succinctly ties together the concepts presented above. In the vadose zone, capillary phenomena are the dominant mechanisms controlling the movement and distribution of DNAPL. In this situation, DNAPL can be either the wetting or nonwetting fluid, depending on the moisture content of the media. In dry media where DNAPL and air occupy the pore spaces, the DNAPL is usually the wetting fluid and will coat the geologic media and preferentially occupy the smaller pore spaces. Where DNAPL is the wetting fluid, capillary forces enhance DNAPL entry into fine-grained media. More typically, the vadose zone is partly saturated or water-wet, resulting in DNAPL, water, and air occupying the pore spaces. Water will usually be the wetting fluid with respect to DNAPL and will coat the geologic media and preferentially occupy the smaller pore spaces. DNAPL will be wetting with respect to air and will coat the water, situating itself between the water and air phases. In this situation, capillary forces will act as a barrier to DNAPL entry into fine-grained media. When a dry medium with DNAPL as the wetting fluid is invaded by water, DNAPL is displaced from the solid surfaces by the water.

After a DNAPL mass has moved through the vadose zone, a part of the DNAPL will be retained by capillary forces as residual DNAPL. Values of residual saturation of chlorinated solvents in

the vadose zone typically range from 0.01 to 0.10 for dry sands and 0.02 to 0.20 for moist sands (Schwille 1988; Poulsen and Kueper 1992; and Cohen and Mercer 1993). DNAPL may be retained as films, wetting pendular rings, wedges surrounding aqueous pendular rings, and as nonwetting blobs in pore throats and bodies (Cohen and Mercer, 1993).

Two processes in the vadose zone work to deplete a DNAPL mass: volatilization into the air phase and dissolution into water. Direct volatilization of DNAPL into the soil gas is generally the most significant mechanism for depletion of chlorinated DNAPL's from the vadose zone (Pankow and Cherry, 1996). The higher the vapor pressure of a compound, the more readily it volatilizes. Additionally, DNAPL that dissolves into water in the vadose zone would also be available to volatilize into the soil gas or sorb to solid surfaces. Subsequently, sorbed contaminant may be remobilized through volatilization or dissolution.

Vapor-phase contamination, whether from direct volatilization or dissolution and then volatilization, is a source for a dissolved-phase plume in the ground water, either from dissolution into infiltrating recharge water or diffusion at the water-table surface. The vapor-phase contamination will move by diffusion and sink by density-driven advection. The higher the relative vapor density, the greater the tendency for the vapor-phase contamination to sink. These processes will spread the source for the dissolved ground water plume over a larger area. Diffusive loss of vapors to the atmosphere can occur, but will be limited if the ground surface is covered with vegetation or finer-grained layers which will restrict vapor movement (Pankow and Cherry, 1996).

Below the water table, where DNAPL and water occupy pore space, DNAPL is usually the nonwetting fluid and must overcome capillary forces to enter the smaller pore spaces occupied by the water. DNAPL will continue to move downward under the force of gravity until a finer-grained layer presents a capillary barrier. The DNAPL will then be diverted laterally, seeking a path downward, or will pool at the barrier until significant pressure builds to penetrate the capillary barrier.

DNAPL pools in porous media typically are wide and shallow. Compared with residual DNAPL, pools of DNAPL have less surface area per volume in contact with ground water. DNAPL pools can persist for long periods of time. The rate of dissolution from a DNAPL pool

is controlled by the vertical dispersion and subsequent removal of the dissolved phase by the moving ground water.

As in the vadose zone, the trailing edge of the DNAPL mass will leave residual DNAPL trapped by capillary forces as isolated blobs and ganglia. Values of residual saturation of chlorinated solvents in porous media in the ground-water zone have been measured in the range from 0.15 to 0.40 (Anderson, 1988). Residual saturation values in the ground-water zone are normally greater than the values in the vadose zone because the fluid density ratio (DNAPL to air as compared to DNAPL to water) favors greater drainage in the vadose zone and, as the nonwetting fluid in the ground-water zone, DNAPL is held in the larger pore spaces (Cohen and Mercer, 1993). The dominant natural process to remove residual DNAPL below the water table is dissolution into ground water. The residual DNAPL provides a source for dissolved-phase ground water plumes (EPA, 2004).

Data collected at the Site regarding evidence of DNAPL indicates that the DNAPL has migrated in the manner describe above (Section 4.4).

5.4.2 <u>Fate of Organic Compounds in Groundwater</u>

Multiple processes affect the fate of SRCs in groundwater. The combination of Site-specific physical, chemical, and biological factors produces unique transport conditions for a given site. Additionally, these conditions may even vary along the transport pathway. As a result of these factors, transport of some compounds in groundwater is often non-conservative, meaning that, as solutes, some compounds generally travel slower than the average rate of groundwater flow (Fetter, 1999). This limitation in the rate of solute transport is referred to as retardation. In addition, processes such as biodegradation can reduce the concentration (and mass) of the solute being transported, although the rate of transport may not be affected. In some instances, biodegradation occurs naturally in the groundwater system and is commonly referred to as natural attenuation (Center for Public Environmental Oversight, 1998).

5.4.2.1 Physical and Chemical Retardation

During groundwater transport, some compounds may be subject to retardation by various physical and chemical factors that degrade or otherwise reduce concentrations. These are also sometimes classified as abiotic factors. Each of these factors is described in the following sections:

Physical Retardation

Abiotic factors include such physical factors as dilution, volatilization, photodegradation, and thermal degradation. Additionally, sorption may occur as a result of either physical or chemical factors, but is discussed under chemical retardation.

- Dilution is simply a decrease in concentration resulting from the mixing of waters with different solute concentrations. Recharge, for example, may locally result in dilution. It should be noted that dilution could result in a decrease in concentration, but without a reduction in total solute mass in the system. In the CSM study area, dilution by recharge occurs at the GWTS where treated effluent is returned to the alluvial aquifer (Section 6.0). No other significant sources of recharge are known to occur in the study area.

- Volatilization is a partitioning of organic compounds between a dissolved aqueous phase and a gaseous phase. This partitioning is a function of the vapor pressure of a VOC as well as the ambient environmental conditions. Vapor pressures for the commonly detected organic compounds are listed in Table 4-8. Conditions within the vadose zone overlying the groundwater table, therefore, can control the degree of volatilization. While volatilization reduces the concentration of the VOC and SVOC solutes in groundwater, their liberation from the free water surface can locally increase the concentration in soil gas occupying voids in the overlying soils.

- Photodegradation is a process whereby spectral energy, such as ultraviolet light, acts to destroy molecular bonding, thereby causing oxidation, cleavage, or other types of alteration. Because groundwater flow occurs in the subsurface, photodegradation of organic compound solutes is negligible.

- Thermal degradation, like photodegradation, is not a significant factor in groundwater transport of organic compound solutes, owing to the relatively constant temperatures encountered in the subsurface.

Chemical Retardation

Chemical retardation in the context of groundwater transport of solutes is largely dependent on the properties of the soil matrix. The parameter that relates the degree of partitioning of a particular solute between the water and aquifer matrix is known as the distribution coefficient (K_d) and, for organic solutes, is equal to the product of K_{oc} and f_{oc}. The retardation factor for a particular VOC can be estimated based on the K_d, the bulk density of the soil/groundwater system, and the porosity (Fetter, 1999).

Within the CSM study area, sorption onto clay surfaces may be more important than onto carbonaceous materials due to low f_{oc} values (Section 5.2). While the organic carbon content of the Qal deposits is low, the presence of organic chemicals (e.g., benzene) in groundwater can locally increase both the available organic carbon content and retardation factors for other SRCs within the alluvial aquifer.

Sorption of trace metals onto soil may occur onto clay surfaces, iron oxides, or carbonaceous materials. Sorption is expected to be the main contributor to retardation of the metals in the study area.

5.4.3 Biological and Biochemical Degradation Processes

Biological and biochemical processes can act on chlorinated organic compounds to degrade the compounds to various breakdown, or daughter products. The typical primary processes for these organic compounds that may occur in the CSM study area include reductive de-chlorination, oxidative degradation, and anaerobic bio-degradation. Degradation of trace metals is not expected to be a significant process in the study area.

5.4.3.1 Reductive Dechlorination

Reductive dechlorination is the most common anaerobic process for degrading chlorinated compounds. In this process, hydrogen atoms are sequentially substituted for a chlorine atom in the contaminant molecules. The major requirement for reductive dechlorination is the presence of other organic compounds, such as fuels, that can serve as the food source. Reductive

dechlorination involves the removal of chlorine atoms from polychlorinated molecules as a result of microbial mediation. In this process, the chlorinated VOC acts as a terminal electron acceptor (TEA). Favorable conditions for this type of destruction include a strongly reducing environment and a source of carbon, serving as an electron donor in the metabolism. Anaerobic conditions (i.e. low dissolved oxygen levels) measured in the majority of the alluvial aquifer groundwater monitor wells at the Site and the presence of an organic carbon source (e.g. benzene) in the alluvial aquifer indicate that favorable conditions for reductive dechlorination exist at the Site for some VOCs.

5.4.3.2 Oxidative Degradation

Oxidative degradation of chlorinated organic compounds can be accomplished by either aerobic or anaerobic microbes. Aerobic destruction requires the presence of oxygen, whereas anaerobic destruction uses a surrogate, such as nitrate, iron, sulfate, or methane, as a TEA. Oxidative degradation favors less chlorinated VOCs, such as benzene and DCBs. For more highly chlorinated VOCs, enhancement is required.

5.4.3.3 Hydrolysis

Chemical reactions, in which substances are broken down without the help of living organisms, are generally less significant than the effects of biological reactions. However, contaminants may react directly with compounds in the soil or groundwater. The primary chemical degradation process is referred to as hydrolysis. Hydrolysis is a chemical substitution reaction in which hydrogen ions in water react with organic molecules, replacing the chlorine atoms. However, unlike reductive chlorination (see above), living organisms play no part in the reactions. The amount of clay in the soil and its pH also influence these reactions. The by-products of hydrolysis are acids and alcohols that biodegrade easily. Hydrolysis is not expected to be a significant process over most of the Site due to the relatively low clay content of the aquifer matrix and the neutral pH conditions of the groundwater. However, areas of higher pH do exist in some areas west of the Montrose Former Plant Site.

6.0 GROUNDWATER TREATMENT SYSTEM

The GWTS is operated under a Consent Order between the State of Nevada and Stauffer and Montrose to remediate contaminated groundwater (State of Nevada, 1983). The GWTS has operated since December 1983. Presently, the GWTS is operated by Pioneer with technical assistance provided by Montrose and SMC.

The purpose of the GWTS is to extract and treat contaminated alluvial aquifer groundwater migrating northward from the Site and the Former BMI Landfill. The GWTS utilizes 13 extraction wells to extract contaminated groundwater from the alluvial aquifer (Figure 6-1). The flow from four extraction wells (extraction wells E3, L, F, and G) having disproportionably high VOC concentrations is routed through a temporary carbon adsorption pre-treatment unit to reduce the VOC load on the downstream air stripper. The pre-treated groundwater is then combined with extracted groundwater from the remainder of the extraction wells and treated using air-stripping followed by activated carbon adsorption. The treated groundwater is then returned to the alluvial aquifer downgradient of the extraction wells via three below-grade recharge trenches.

The following sections provide an overview of:

- Historical evaluations and upgrades to the GWTS;

- Current operations and system configuration;

- A summary of NDEP Action Item No. 2 Issues;

- Results of the extraction well evaluation program;

- Capture and control of groundwater containing VOCs, and

- A summary of the overall GWTS performance (Table 6-1).

6.1 SYSTEM EVALUATIONS AND UPGRADES HISTORY

The follow sections discuss some of the primary evaluations and upgrades that have been performed with regard to the GWTS since preliminary design activities began in 1982.

6.1.1 Ground-Water Intercept System Hydrogeologic Investigation

In 1982, Stauffer conducted a hydrogeologic assessment downgradient of the former Montrose and Stauffer facilities to supplement hydrogeologic data previously collected in the area of the proposed GWTS (Stauffer, 1983; Geraghty & Miller, Inc., 1980). The investigation included soil borings, lithologic characterization, monitor well construction, aquifer testing, water level measurement, and limited water quality sampling. Hydrogeologic data collected during the 1982 assessment identified and delineated coalescing paleochannels downgradient of the former facilities. The location of these paleochannels determined the appropriate location for the GWTS, the location and design of the extraction wells and recharge trenches, and the selection of upgradient and downgradient monitoring locations pursuant to the request of NDEP (Stauffer, 1983).   The GWTS began operation in December 1983.

6.1.2 GWTS Evaluation in 1998

In 1998, an evaluation of GWTS performance was conducted (HLA, 1998). The evaluation included a review of historical monitoring data collected during the approximately 15-year operation of the GWTS and a qualitative and quantitative analysis of system performance. As part of the performance review, a computer-based database system was developed for the management and analysis of data. The 1998 GWTS evaluation report concluded the following:

- The GWTS effectively captured impacted groundwater in the alluvial aquifer;

- Based on available data collected during approximately 15 years of operation, the GWTS was expected to continue to effectively capture impacted groundwater for the foreseeable future, subject to adequate ongoing maintenance, and

- The existing GWTS was effectively treating impacted groundwater by reducing VOC concentrations to required levels that allowed recharge of the treated water downgradient of the extraction wells (HLA, 1998).

6.1.3 2003 Recharge Trench Investigation

An investigation of the recharge trench area was conducted in 2003. The purpose of the investigation was to assess conditions and determine if conditions had changed in such a way as to affect recharge operations. Subsurface conditions were evaluated to determine how long-term operation of the recharge portion of the GWTS may have adversely affected subsurface lithology and negatively impacted recharge operations. During the investigation, five exploratory trenches were excavated using a backhoe to approximate depths of 10 feet. Three of the exploratory trenches, two at the western recharge trench and one at the eastern recharge trench, were excavated to verify recharge trench construction, describe the subsurface lithology, and investigate for evidence of recharge trench clogging due to bacterial growth and/or precipitation of mineral deposits. The remaining two exploratory trenches were excavated outside the area of influence of the GWTS to evaluate undisturbed subsurface background conditions. Observations made during the exploratory excavation activities determined that the recharge trenches were not affected or impeded by bacterial growth or mineral deposits. It was concluded that the trenches were functioning as designed and that no deterioration was apparent.

The investigation also included the construction of four new monitor wells identified as TMW-1 through TMW-4 (Geomatrix Consultants, Inc., 2003). The four monitor wells are located near each of the recharge trenches. The monitor wells were installed to evaluate water level conditions in the immediate area of the recharge trenches.

6.1.4 GWTS Renovation and Upgrades

Due to the age of the GWTS, an extensive renovation and upgrade of the GWTS was initiated by the Companies between 2002 and 2006 (Montrose, 2004). The renovation and upgrade included phased replacement of most of the existing treatment equipment, addition of activated carbon adsorption to the treatment train, improvement of the control system for the distribution of treated groundwater to the recharge trenches, and enhancement of the monitoring of downgradient water quality. Detailed descriptions of the renovations and upgrades were presented, as they were completed, in GWTS monitoring reports submitted to NDEP on a quarterly basis (H+A, 2005a, 2006a, 2006b, 2006d, 2006e, 2006h, 2007a, and 2007b).

6.2 <u>CURRENT OPERATIONS</u>

This section summarizes the GWTS operation and performance since the system renovations and upgrades were initiated in 2002 and completed in 2006. Detailed descriptions of recent routine operations and maintenance, results of Consent Order groundwater monitoring, and the status of emissions from the air stripper for air permit compliance are presented in quarterly GWTS monitoring reports submitted to NDEP (H+A, 2005a, 2006a, 2006b, 2006d, 2006e, 2006h, 2007a, and 2007b).

6.2.1 <u>Overview of GWTS Operations</u>

Impacted groundwater extracted from the alluvial aquifer by a line of 13 extraction wells is conveyed to a water treatment facility for removal of contaminants before the water is returned to the aquifer via a line of subsurface recharge trenches. In recent years the various upgrades to the extraction wells, treatment facilities, and recharge trenches have increased system reliability and improved the capacity to remove contaminants. As a result, system downtime has been reduced and the amount of contaminants removed each month has increased.
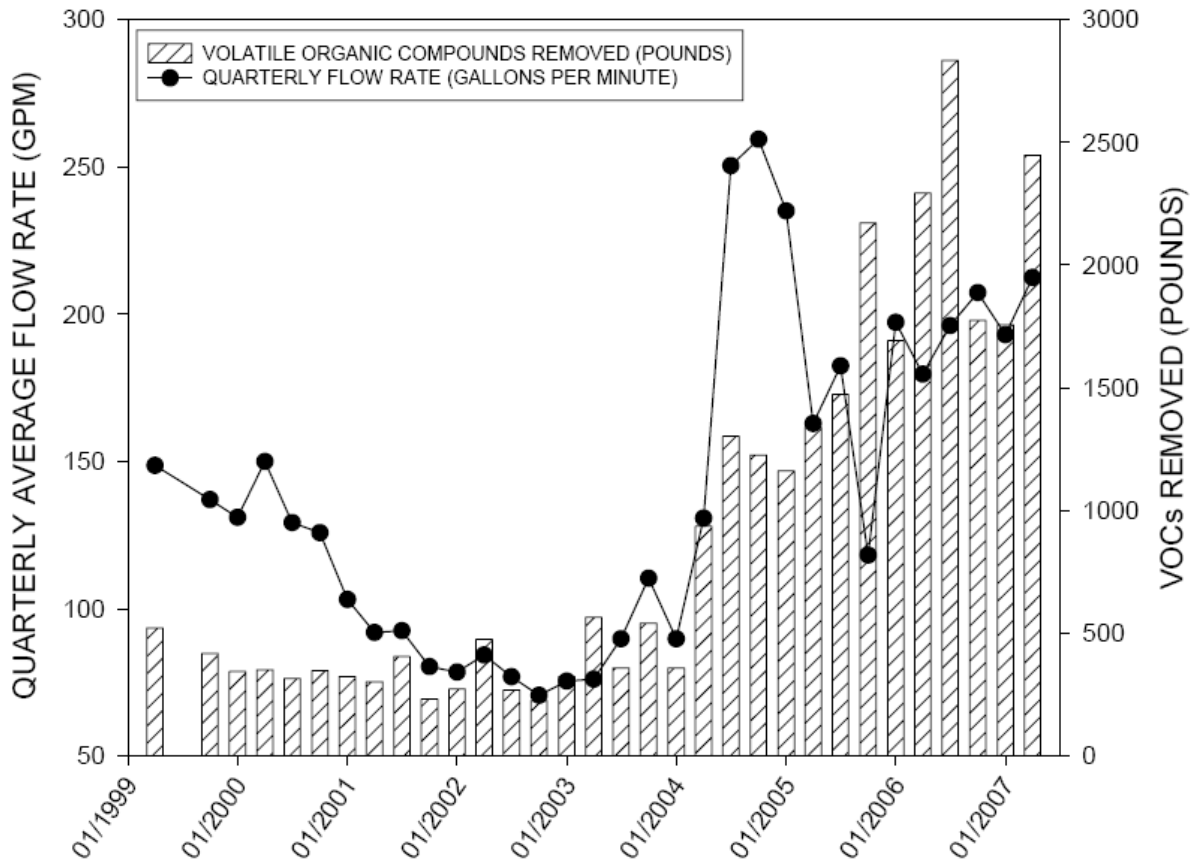
References: (H+A, 2005a, 2006a, 2006b, 2006d, 2006e, 2006h, 2007a, and 2007b).

Air stripping continues to be the primary treatment technology used to remove VOCs. Liquid-phase carbon adsorption has since been added for polishing to remove residual VOCs and to remove pesticides and SVOCs not removed by air stripping. For extraction wells with elevated concentrations of VOCs, a pre-treatment process using carbon adsorption was installed in 2006 to control influent concentrations to the air stripper

Chemical feed systems are used to add biodegradable biocides and sequestering agents to the groundwater upstream from treatment to control development of biofilms and mineral deposits that could lead to fouling or clogging of the air stripper trays or carbon adsorption vessels. Multi-bag filters are used upstream from the air stripper and carbon adsorption vessels to remove any suspended solids, sediment, and/or biomass (from the use of biocide) that could lead to clogging or fouling of the treatment facilities. As a final treatment step, multi-bag filters are used to remove any suspended solids, biomass, or carbon filter fines from the treated

groundwater before it is returned to the alluvial aquifer via the recharge trenches. The treated water conveyed to the recharge trenches is proportional to the rate of flow received from the extraction wells.

6.2.2 <u>Extraction Wellfield Operation</u>

The current extraction wellfield operates at an average flow rate ranging from 180 to 280 gpm. Individual extraction well rates range between 10 and 70 gpm. The extraction well flow rates vary across the extraction zone due to the subsurface lithology and variations in saturated thickness. The majority of the extraction volume is currently derived from the western portion of the wellfield (extraction wells A, B, and C) (Figure 6-1). These extraction wells are located in the western paleochannel that exists in the vicinity of the GWTS (Figure 6-2). The extraction wells in the eastern portion of the wellfield (extraction wells E3 through I) extract less water than wells in the western portion. These extraction wells are located in the eastern paleochannel that exists in the vicinity of the GWTS.

The area between the two paleochannels forms a buried northeast-southwest trending ridge in the Muddy Creek Formation beneath the central portion of the extraction wellfield (Figure 6-2). This feature is referred to as an interfluve. The thickness of saturated alluvium in the vicinity of the interfluve is limited and extraction wells located in this area tend to be shallower and have lower pumping capacities compared to extraction wells located in the paleochannel areas.

Routine maintenance for the extraction wellfield includes well redevelopment to restore pumping capacity, occasional replacement of poorly performing wells, and the replacement of worn or broken equipment, including pumps, valves, piping and other appurtenances.

6.2.3 <u>Groundwater Treatment Facilities Operation</u>

The groundwater treatment facilities include the following major components: 1) the selective wellhead treatment system; 2) an influent manifold to collect and measure flows from the extraction wells including the flows routed through the selective treatment system; 3) chemical feed systems for biocide and sequestering agent injection; 4) an influent multi-bag filter; 5) a shallow-tray air stripper; 6) equalization tank and effluent pumps; 7) liquid-phase GAC vessels;

8) a dedicated carbon vessel backwash system; 9) an effluent multi-bag filter; and 10) a complete control panel with a programmable logic controller and supervisory control and data acquisition system with remote access capability. A description of each of these processes has been prepared and submitted to NDEP (H+A, 2007a).

The treatment facilities are designed to operate continuously except for short time periods required to inspect components or perform maintenance. In order to maintain a high percentage of runtime, the design of the treatment facilities has incorporated various component bypasses and alternative flow options throughout the system to perform most of the routine maintenance without shutting down system operations.

6.2.4 Recharge Trench Operation

The treated water is returned to the alluvial aquifer using recharge trenches. The recharge trenches are constructed in a line about 1,800 feet long perpendicular to the groundwater flow direction. The recharge trenches are located 100 to 150 feet downgradient from the extraction wells (Figure 6-1). During 2006, the western trench typically received treated water at a rate of 100 to 120 gpm (near its estimated capacity) or about half of the total system flow; the eastern trench received treated water at a rate of 65 to 80 gpm (near its estimated capacity) or about 35 percent of the total system flow; and the center trench received treated water at a rate of 35 gpm which is about 15 percent of the total system flow. Water level data near the center trench indicate minimal water level rise suggesting that the center trench has additional recharge capacity (H+A, 2005a, 2006a, 2006b, 2006d, 2006e, 2006h, 2007a, and 2007b).

6.2.5 Monitoring and Reporting

Groundwater levels are routinely monitored at the extraction wells, monitor wells, and piezometers located in the vicinity of the GWTS. A network of over 100 monitor wells and piezometers is used to measure water levels for routine evaluations of GWTS performance and to collect water samples to monitor groundwater quality for Consent Order compliance purposes.

The Consent Order requires quarterly sampling at specified wells located upgradient and downgradient of the extraction wellfield and at the influent and effluent to treatment facilities. Additional sampling is performed at selected wells and at the treatment facilities to evaluate changes in performance resulting from renovation and upgrades to facilities; and changes in operations. The monitoring reports are prepared quarterly and submitted to NDEP as required by the Consent Order.

A special groundwater sampling program at a monitor well transect downgradient of the GWTS has been conducted by the Companies approximately on a quarterly basis since March 2004 as part of the GWTS renovation and upgrade program (Montrose, 2004). Through the third quarter 2006, two transects were monitored and were called the northern and southern transects (Figure 6-1). Starting in the fourth quarter 2006, the northern transect, comprised of monitor wells H-10A and MC-62, was removed from the special monitoring program due to impending destruction of the wells due to planned development. Replacement of these monitor wells is being discussed with NDEP. The seven transect monitor wells and piezometers currently in use are located downgradient from the GWTS and across the entire width of the alluvial aquifer where VOCs have been historically detected.

The purpose of the transect sampling program is to evaluate the effectiveness of the GWTS by monitoring concentrations of selected VOCs, pesticides, and organic acids in groundwater immediately downgradient of the GWTS. The monitoring program allows evaluation of the effectiveness of the system before the groundwater migrates farther downgradient to the Consent Order downgradient wells and provides the opportunity for a faster response to changes in downgradient groundwater conditions. The results of this sampling are summarized in the quarterly GWTS monitoring reports (H+A, 2005a, 2006a, 2006b, 2006d, 2006e, 2006h, 2007a, and 2007b).

6.3 SUMMARY OF ACTION ITEM NO. 2 TECHNICAL MEMORANDUM

A technical memorandum was prepared to respond to issues raised by NDEP regarding the efficacy of the GWTS. The efficacy issues pertain to defining specific geologic and hydrogeologic cond-itions in the GWTS area and their possible impacts on the operation of the

GWTS. These issues are collectively referred to as Action Item No. 2 issues and include the following:

- The presence and extent of caliche in the alluvium and its impact on the capture efficiency of the GWTS;

- The lithologic nature of the alluvium/Muddy Creek Formation contact and the relative placement of extraction well screens in the GWTS area, and

- The potential presence of DNAPL in the GWTS area.

The Action Item No. 2 evaluations were conducted in an area of approximately 130 acres surrounding the GWTS. Lithologic logs from 96 wells within this area were available and reviewed. The lithologic logs used for the evaluation included logs from boreholes, monitor wells, piezometers, and extraction wells installed in the GWTS area from 1979 to the present day.

Some form of caliche is found in most of the area within the alluvium as caliche was identified in approximately half of the available lithologic logs examined. Review of the available lithologic logs indicates that the caliche layers are not laterally continuous throughout the area. Many of the caliche layers are present at the contact between the alluvial aquifer and the underlying Muddy Creek Formation.

A review of all available lithologic data does not indicate the presence of laterally-extensive caliche layers in the GWTS area. Recent water level and aquifer test data also suggest that no hydraulic boundary condition, such as laterally-extensive caliche layers or other lower hydraulic conductivity sediments, exists within the alluvium in the vicinity of the GWTS.

6.3.1 Lithology of the Alluvium/Muddy Creek Contact and Extraction Well Construction

Lithologic logs were evaluated to better determine the nature of the contact between the shallow alluvium and the Muddy Creek Formation and the extent of transition, if any, between these units. This task was difficult because many of the logs only noted the depth of the contact with no additional specific information. However, where sufficiently detailed information was

available, the lithologic logs were reviewed to determine the nature of the contact and any observable transition zone.

Based on the available information, seven out of the ten active extraction wells evaluated are completed to at least the top of the Muddy Creek Formation. The three active extraction wells not completed to the Muddy Creek Formation are within two feet of the contact. Based on this information, it is likely that all of the extraction wells are capturing any potentially contaminated groundwater from the transition zone, even in those wells where a very thin portion of the transition zone exists below the depth of the well.

6.3.2 <u>Potential for Dense Non-Aqueous Phase Liquids in Groundwater Treatment System Area</u>

To date (July 2008) no evidence of DNAPL has been found in the vicinity of the GWTS as a result of the following investigation and monitoring programs:

1. Routine gauging of monitor wells in the vicinity of the GWTS with a product/water interface probe for the presence of DNAPL has found no evidence of DNAPL to be present at the GWTS.

2. There are no known sources of DNAPL within a minimum of 450 feet of the well field.

3. Direct evidence of DNAPL has not been observed during drilling of extraction wells and monitor wells in the vicinity of the GWTS.

4. Groundwater and soil vapor measurements in the region between the known source areas.

Reviewing extraction well data from April 2005 to the present, the same time period discussed in the subsections of Section 4.3, the maximum concentrations of representative SRCs in the area of the GWTS were much less than upgradient concentrations in areas where DNAPL is expected to occur. Benzene was detected above laboratory MRLs in 40 of the 47 groundwater analyses from the extraction wells. Detectable benzene concentrations in the extraction wells ranged from 3 to 38,000 ug/l. Benzene was detected in 36 of the 47 groundwater samples at concentrations above the MCL for benzene of 5 ug/l (approximately 77 percent of the total

number of samples). The maximum detected concentration of benzene, 38,000 ug/l, is at 2.2 percent of the solubility of benzene in water.

Chlorobenzene was detected above laboratory MRLs in 42 of the 47 groundwater analyses from the extraction wells. Detectable chlorobenzene concentrations in the extraction wells ranged from 0.37 to 30,000 ug/l. Chlorobenzene was detected in 37 of the 47 groundwater samples at concentrations above the MCL for chlorobenzene of 100 ug/l (approximately 79 percent of the total number of samples). The maximum detected concentration of chlorobenzene, 30,000 ug/l, is at 6.4 percent of the solubility of chlorobenzene in water.

1,2-DCB was detected above laboratory MRLs in 59 of the 73 groundwater analyses from the extraction wells. Detectable 1,2-DCB concentrations in the extraction wells ranged from 0.61 to 850 ug/l. 1,2-DCB was detected in 7 of the 73 groundwater samples at concentrations above the MCL for 1,2-DCB of 600 ug/l (approximately 10 percent of the total number of samples). The maximum detected concentration of 1,2-DCB, 850 ug/l, is at 0.5% of the solubility of 1,2-DCB in water.

1,4-DCB was detected above laboratory MRLs in 56 of the 73 groundwater analyses from the extraction wells. Detectable 1,4-DCB concentrations in the extraction wells ranged from 0.92 to 1,300 ug/l. 1,4-DCB was detected in 39 of the 73 groundwater samples at concentrations above the MCL for 1,4-DCB of 75 ug/l (approximately 53 percent of the total number of samples). The maximum detected concentration of 1,4-DCB, 1,300 ug/l, is at 1.8% of the solubility of 1,4-DCB in water.

Chloroform was detected above laboratory MRLs in 37 of the 47 groundwater analyses from the extraction wells. Detectable chloroform concentrations in the extraction wells ranged from 1.9 to 16,000 ug/l. Chloroform was detected in 18 of the 47 groundwater samples at concentrations above the MCL for chloroform of 80 ug/l (approximately 38 percent of the total number of samples). The maximum detected concentration of chloroform, 16,000 ug/l, is at 0.2% of the solubility of chloroform in water.

Carbon tetrachloride was not detected above laboratory MRLs in any of the 47 groundwater analyses from the extraction wells.

Tetrachloroethene was detected above laboratory MRLs in 20 of the 47 groundwater analyses from the extraction wells. Detectable tetrachloroethene concentrations in the extraction wells ranged from 1.4 to 170 ug/l. Tetrachloroethene was detected in 16 of the 47 groundwater samples at concentrations above the MCL for tetrachloroethene of 5 ug/l (approximately 34 percent of the total number of samples). The maximum detected concentration of tetrachloroethene, 170 ug/l, is less than 0.1% of the solubility of tetrachloroethene in water.

1,2,4-TCB was detected above laboratory MRLs in 45 of the 73 groundwater analyses from the extraction wells. Detectable 1,2,4-TCB concentrations in the extraction wells ranged from 1.2 to 230 ug/l. 1,2,4-TCB was detected in 25 of the 73 groundwater samples at concentrations above the MCL for 1,2,4-TCB of 70 ug/l (approximately 34 percent of the total number of samples). The maximum detected concentration of 1,2,4-TCB, 230 ug/l, is less than 1.0% of the solubility of 1,2,4-TCB in water.

Bis(4-chlorophenyl) disulfide was not detected above laboratory MRLs in any of the 13 groundwater analyses from the extraction wells.

Future Planned Investigations

Additional field work is scheduled to be conducted in the vicinity and downgradient of the GWTS pending completion of access arangemens in the third quarter 2008 (H+A, 2007d and 2008a). Direct and indirect methods of determining DNAPL presence or absence will be used consistent with those used during the drilling of borings in the vicinity of the Montrose Closed Ponds Area, Former Tank Farm, and Former Plant Site (Section 4.4, Figure 2-2).

6.4 EXTRACTION WELL PERFORMANCE EVALUATION PROGRAM

A preliminary assessment of groundwater capture in the vicinity of the extraction wellfield was conducted based on analysis of water level data collected in May 2006. The assessment indicated that the extent of the cones of depression around wells located in the central area of the wellfield was uncertain based on available data. As a result, four extraction wells (C, J, D2, and E3) located in the central portion of the wellfield were selected for testing. Recovery/drawdown tests were conducted on the four extraction wells to evaluate the extent of

drawdown and determine if the Consent Order required overlapping cones of depression have been established (H+A, 2007c).

The tests were conducted by shutting off the extraction well to be tested and monitoring the water level recovery in the extraction well and surrounding monitor wells until an approximate static water level condition was achieved. The extraction well was then restarted and the drawdown was monitored in a similar fashion. The testing was completed while the wellfield was operating, so the GWTS was operated as consistently as practical to create an approximate steady state water level condition in the vicinity of the tested wells. This was achieved by maintaining as constant a flow rate as possible from each extraction well and to each recharge trench.

This testing showed that the cones of depression overlapped at the test flow rates, but that the efficiency of capture could be markedly improved by adding an additional extraction well in the central portion of the wellfield. The results of the extraction well evaluation and recommendations for future actions were summarized and submitted to NDEP (H+A, 2007c).

6.5 CAPTURE AND CONTROL OF GROUNDWATER CONTAINING SRCS

The following sections outline and demonstrate the overall effectiveness of the GWTS based primarily on observed groundwater chemistry upgradient and downgradient of the extraction well field, treatment system and the associated recharge trenches.

6.5.1 Groundwater Chemistry

The SRCs discussed in detail in Section 4.0 were also further evaluated to determine the effectiveness of the GWTS in capturing and treating alluvial aquifer groundwater. Only those SRCs that are detected in the groundwater samples collected from alluvial aquifer groundwater monitor wells upgradient of the GWTS and are detected in the groundwater samples collected from the GWTS extraction wells are discussed in this section. The SRCs include the following chemical groups/compounds:

- VOCs – benzene, chlorobenzene, 1,2-DCB, 1,4-DCB, chloroform, and PCE;

- SVOCs – 1,2,4-TCB;

- Organic Acid Compounds – DMPT;

- Pesticides – alpha-BHC, beta-BHC, and gamma-BHC, and

- Metals (arsenic); and general chemicals (TDS).

In order to evaluate the effectiveness of the GWTS in capturing and treating SRCs, the chemical concentration contour maps described in Section 4.0 were reviewed to determine if concentrations of the SRCs in groundwater downgradient of the GWTS are significantly reduced compared to concentrations in groundwater upgradient of the GWTS. The results of the review of each of the specific chemical groups/compounds are discussed in the following sections. Discussion begins with the chemical groups of VOCs and SVOCs as the GWTS was primarily designed to remove these compounds and concentrations of these compounds are significantly reduced by the GWTS.

6.5.1.1 Volatile Organic Chemicals

Benzene

Review of the recent chemical concentration contour maps indicates that benzene concentrations upgradient of the GWTS ranged from 0.91 to 620,000 ug/l, and concentrations of benzene in groundwater samples from the extraction wells ranged from non-detect to 33,000 mg/l (Figure 4-5). Review of Figure 4-5 also indicates that benzene concentrations downgradient of the GWTS are generally less than 2 ug/l with the exception of three small areas of residual concentrations ranging from 3 to 410 ug/l. Only five monitor wells produce groundwater samples that contain benzene at a concentration greater than the MCL of 5 ug/l and only one groundwater sample from monitor well MC-50 contained benzene at a concentration greater than 10 ug/l.

Chlorobenzene

Review of the chlorobenzene concentration contour map indicates that detectable chlorobenzene concentrations upgradient of the GWTS range from 2.0 to 320,000 ug/l and concentrations in groundwater samples from the extraction wells range from non-detect to

24,000 mg/l (Figure 4-8). Downgradient of the GWTS, detectable chlorobenzene concentrations are generally less than 10 ug/l except for two small areas downgradient of the GWTS where residual chlorobenzene concentrations are greater than the MCL of 100 ug/l. The concentration in the groundwater sample from monitor well MC-50 was 170 ug/l and the groundwater samples from monitor wells H-10A and MC-49 were 110 and 230 ug/l, respectively (Figure 4-8).

1,2- and 1,4-Dichlorobenzene

Review of Figure 4-10 indicates that 1,2-DCB concentrations upgradient of the GWTS range from 0.47 to 27,000 ug/l and concentrations in groundwater samples from the extraction wells range from non-detect to 780 ug/l. Downgradient of the GWTS, 1,2-DCB concentrations are generally less than 10 ug/l (with the exception of a concentration of 64 ug/l at monitor well H-10A), and all groundwater samples collected from wells downgradient of the GWTS are well below the MCL of 600 ug/l. Similarly, 1,4-DCB concentrations upgradient of the GWTS range from 1.1 to 25,000 ug/l and concentrations in groundwater samples from the extraction wells range from non-detect to 1,300 mg/l. Downgradient of the GWTS, 1,4-DCB concentrations ranged from 0.37 to 100 ug/l and only one groundwater sample from monitor well H-10A exceeded the MCL of 75 ug/l for this compound (Figure 4-12).

Chloroform

Chloroform concentrations in groundwater samples collected from monitor wells upgradient of the GWTS are as high as 130,000 ug/l. Groundwater samples collected from the extraction wells range from non-detect to 8,000 ug/l, but immediately downgradient of the GWTS, in the area between the GWTS and Boulder Highway, chloroform concentrations in groundwater samples are generally less than 20 ug/l (Figure 4-16). However, elevated chloroform concentrations in groundwater samples, ranging from 88 to 900 ug/l, are also detected in the area northeast of the Boulder Highway and elevated chloroform concentrations are reported by others to the east of the CSM study area by Tronox and Timet indicating that elevated chloroform concentrations in groundwater in the northern portion of the CSM study area may be related to other chloroform sources that are not upgradient of, and are not captured by, the GWTS (ENSR, 2005; Timet 2007b).

Tetrachloroethene

Review of the PCE concentration contour map indicates that concentrations upgradient of the GWTS range from 0.35 to 2,600 ug/l and groundwater samples collected from the extraction wells ranged from non-detect to 170 ug/l (Figure 4-20). Similar to the other VOCs, PCE concentrations in groundwater samples collected from monitor wells downgradient of the GWTS are very low, generally less than the MCL of 5 ug/l. There are three monitor wells in two small areas where residual PCE concentrations are greater than the MCL. One area of residual PCE is downgradient of the GWTS, in the area between the GWTS and Boulder Highway. In this area monitor wells MC-62 and PC-40 produce groundwater with concentrations of PCE at 7.5 and 6.7 ug/l, respectively (Figure 4-20). Another small area where PCE concentrations in groundwater exceed the MCL is an area northeast of the Boulder Highway where a groundwater sample from monitor well PC-67 contained PCE at a concentration of 14 ug/l. This area is not in the groundwater flow path downgradient of the GWTS and is not likely related to sources within the Site.

6.5.1.2 Semi-Volatile Organic Chemicals

Review of the concentration contour map of the SVOC 1,2,4-TCB indicate that concentrations of this compound in groundwater samples collected from monitor wells upgradient of the GWTS range from 0.38 to 700 ug/l. Higher concentrations in groundwater may exist upgradient of the GWTS, however due to matrix interference many samples have high detection limits. 1,2,4-TCB concentrations in groundwater samples collected from the GWTS extraction wells ranged from less than 5 to 200 ug/l (Figure 4-14). However, no groundwater samples collected downgradient of the GWTS contained detectable 1,2,4-TCB concentrations greater than the MCL of 70 ug/l for this compound; concentrations ranged from 0.64 to 44 ug/l (Figure 4-14).

6.5.1.3 Organic Acids

Review of Figure 4-39 indicates that concentrations of the organic acid compound DMPT in groundwater samples collected upgradient of the GWTS ranged from 140 to 4,500,000 ug/l and groundwater samples collected from the extraction wells range from less than 2,500 to 20,000 ug/l. Detection limits for DMPT vary widely from approximately 100 to 10,000 ug/l.

Concentrations of DMPT in groundwater samples immediately downgradient of the GWTS range from 100 to 250 ug/l. Groundwater samples collected from monitor wells farther downgradient of the GWTS contain DMPT concentrations that ranged from that 100 to 4,400 ug/l (Figure 4-39). These data indicate that the GWTS is currently effective at capturing and reducing concentration of this compound and that the sporadic detections of this compound in the area downgradient of the GWTS may be residual concentrations or may be related to other sources.

6.5.1.4 Pesticides

Upgrades to the GWTS to treat for pesticides have been made, the concentrations of BHC isomers immediately downgradient of the GWTS are significantly lower in comparison with upgradient concentrations.   For example, concentrations of alpha-BHC in alluvial aquifer groundwater monitor wells decrease from approximately 130 ug/l upgradient of the GWTS (well AA-BW-04A) to concentrations ranging from 0.20 to 1.1 ug/l immediately downgradient of the GWTS (Figure 4-25; wells MC-46, MC-50, MC-51, and MC-53). As shown on Figure 4-27, the presence of gamma-BHC in the alluvial aquifer downgradient of the GWTS at concentrations exceeding the MCL of 0.2 ug/l appears to be limited to an area extending from approximately Warm Springs Road to Boulder Highway (i.e., encompassing monitor wells MC-62 and PC-40). The downgradient extent of this area is defined by alluvial aquifer monitor wells MW-R, PC-31, and PC-64, where gamma-BHC was not detected at or above the laboratory's MRL (ranging from 0.095 to 0.1 ug/l).   Concentrations of beta-BHC (for which an MCL has not been established) downgradient of the GWTS (ranging from less than the laboratory reporting limit to 18 ug/l [at monitor well MC-62]) also exhibit reductions across the GWTS, although less than the reductions observed for the alpha- and gamma-isomers (Figure 4-26).

Alluvial aquifer groundwater upgradient of the GWTS contains small areas of detectable concentrations of 4,4'-DDT and 4,4'-DDE (Figures 4-29 and 4-31). These areas are located at least 1,600 feet upgradient of the GWTS and do not appear to have migrated to the GWTS. There are no MCLs established for 4,4'-DDT and 4,4'-DDE.   These compounds were not detected in groundwater samples collected from extraction wells. Only 4,4'-DDT was detected downgradient of the GWTS at a concentration of 0.12 ug/l in one isolated monitor well, MW-S, located northwest of the City of Henderson Water Reclamation Facility.

6.5.1.5 Metals and General Chemicals

The concentration contour maps for arsenic and TDS were evaluated even though the GWTS is not designed to treat arsenic or reduce TDS. The purpose of the evaluation is to see if the GWTS has any apparent impact on these constituents and because background concentrations of arsenic and TDS are elevated within the CSM study area and the region.

Arsenic concentrations measured in groundwater samples collected from monitor wells upgradient of the Site operations area range from less than 1 to 62 ug/l. Arsenic concentrations in groundwater samples from monitor wells within the Site operations area and upgradient of the GWTS range from 27 to 2,200 ug/l and groundwater samples collected from the extraction wells range from 92 to 270 ug/l. Concentrations of arsenic in groundwater downgradient of the GWTS are similar and range from 9.4 to 270 ug/l indicating the GWTS has little or no impact on arsenic concentrations (Figure 4-41). Similar to chloroform, elevated arsenic concentrations in groundwater samples are also detected to the east of the CSM study area by Tronox and Timet indicating that elevated arsenic concentrations in groundwater in the northern portion of the CSM study area may also be related to other arsenic sources that are not upgradient of, and are not captured by, the GWTS (ENSR, 2005; Timet, 2007b).

Review of the TDS concentration contour map reveals a situation similar to that observed with arsenic. Figure 4-42 indicates that TDS concentrations in groundwater samples collected from monitor wells upgradient of the Site operations areas range from 740 mg/l to 2,000 mg/l. In the area of current and former Site operations, upgradient of the GWTS, groundwater samples contain concentrations of TDS that range from 1,400 to 51,000 mg/l and the samples collected from the extraction wells range from 2,600 to 32,000 mg/l. However, downgradient of the GWTS groundwater samples contain TDS concentrations of 2,600 to 13,000 mg/l indicating that the GWTS may cause mixing or dilution of the highest concentrations, but does not significantly impact TDS concentrations.

6.5.1.6 PCB Congeners, and Dioxin/Furans

PCB Congeners

While a wide range of PCB congeners have been analyzed during the various investigation programs, only 2,2'-dichlorobiphenyl is discussed here because it was the only PCB congener detected above the MCL of 0.5 µg/L. Detectable concentrations of 2,2'-dichlorobiphenyl occurred in 19 of the 23 groundwater samples collected from monitor wells upgradient of the GWTS. The detections were generally less than 0.02 ug/l except for the one detect above the MCL. This detection occurred in monitor well EC-02 at a concentration of 3.7 µg/L.

2,2'-dichlorobiphenyl was also detected in all groundwater samples collected from the extraction wells of the GWTS at concentrations generally below 0.02 µg/L with the exception of 0.0251 µg/L in extraction well "B" and the detection of 0.16 ug/l in extraction well "C".

Detectable concentrations of 2,2'-dichlorobiphenyl occurred in 15 of the 22 groundwater samples collected from monitor wells downgradient of the GWTS. The detections were generally less than 0.004 µg/L except for three wells. These wells, PC-77, PC-86, and PC-97, are located adjacent to the Las Vegas Wash and contained 2,2'-dichlorobiphenyl concentrations that ranged from 0.0407 to 0.104 µg/L.

Dioxin/Furans

Review of Figure 4-35 indicates that 2,3,7,8-TCDD was detected in only one well in the study area. This well, AA-BW-08A, is located approximately 2,400 feet upgradient of the GWTS. The well produced groundwater that contained 2,3,7,8-TCDD at a concentration of 4.4×10^{-4} µg/L which is greater than the MCL of 3×10^{-5} µg/L for this compound. All other samples in the study area were non-detectable for 2,3,7,8-TCDD. 2,3,7,8-TCDD does not appear to have migrated to the GWTS at this time.

6.6 SUMMARY OF OVERALL GWTS PERFORMANCE

To summarize, the GWTS is very effective in removing the compounds from groundwater for which it is designed: the VOCs and the SVOC 1,2,4-TCB. With the treatment upgrades installed in 2004, it is also effective at removing concentrations of organochlorine pesticides. Treatment train chemical concentrations studies have also shown that the GWTS is also effective at removing the organic acid DMPT, but does not significantly affect the concentration of inorganic analytes arsenic and TDS, for which the system was not designed pursuant to the Consent Order (State of Nevada, 1983).

7.0 EXPOSURE PATHWAYS AND POTENTIAL RECEPTORS

Previous sections of this CSM document have described the nature and extent of chemicals within the CSM study area, along with potential transport mechanisms that could disperse chemicals to other media or locations. This section builds upon that analysis to provide a summary of the human and ecological receptors that could be exposed to the SRCs and the routes by which exposures could occur. The synthesis of this collective information is referred to as an exposure pathway.

EPA (1989) has defined the four elements that must exist for an exposure pathway to be considered complete:

- A source and mechanism of chemical release;
- A retention or transport media;
- A point of potential contact by receptors, and
- An exposure route at the contact point.

If any one of these elements is missing, then the exposure pathway is considered incomplete. For example, if human activity patterns and/or the location of potentially exposed individuals prevent contact with the impacted media, then no completed pathways can exist.

This section focuses on the potential contact points and related exposure routes that are relevant for the sources and transport mechanisms previously discussed. Site-specific soils and groundwater beneath and downgradient of the Site contain SRCs and are considered here. Additionally, air, which can contain SRCs as a result of dust generation or volatilization, also is considered. Potentially complete exposure pathways associated with these media are discussed.

Surface water onsite is not considered a potential contact point or exposure route since no permanent surface water bodies exist onsite (Section 3.3). Exposure to chemicals in downgradient groundwater that has discharged to the Las Vegas Wash could theoretically occur and is discussed here.

In some cases, an exposure pathway may be complete but is not significant because: 1) the exposure may be less than that from another pathway involving the same medium at the same exposure point;; 2) the magnitude of exposure has low toxicological significance; and/or 3) the probability of exposure is low and potential risks associated with the pathway are not high (EPA, 1989). Exposure pathways that are potentially complete but are considered insignificant will be discussed as "minor" routes to differentiate them from the "primary" exposures pathways identified for the Site.

The remainder of this section first describes the human receptor populations and their related exposure pathways, followed by a discussion of the ecological receptors and pathways. A graphical representation of the exposure pathway analysis for human and ecological receptors in the study area is presented in Figure 7-1.

7.1 HUMAN RECEPTORS AND EXPOSURE PATHWAYS

The land use within the CSM study area includes both industrial/commercial and residential areas. As such, both residential and worker populations were considered in the exposure pathway analysis. It was assumed that the current land use within the CSM study area would remain the same in the future.

7.1.1 Worker Exposure Pathways

For the industrial/commercial workers at the Site, a total of four exposure scenarios have been identified:

- Indoor workers who spend the majority of their work day indoors;

- Outdoor workers who spend the majority of their work day outside;

- Construction workers who are assumed to contact shallow and subsurface soils, and

- Maintenance workers at the GWTS could potentially contact pumped groundwater.

For indoor workers, the primary exposure media is indoor air. The inhalation exposure route could result from release of volatile SRCs from soils or groundwater. Volatile chemicals released from soil could be transported through ambient air and infiltrate into indoor air. Volatile chemicals in groundwater and subsurface soils could migrate through the vadose zone and infiltrate indoor air through the building foundation. Fugitive dusts generated from wind erosion or soils handling activities could also be transported via ambient air and ultimately infiltrate indoor air. Exposure pathways associated with outdoor soil contact also could occur, though it is expected that contact with outdoor soils would be minor because workers in this scenario are assumed to spend the majority of their workday indoors. Although groundwater in the CSM study area is not used for domestic, agricultural or municpal purposes, the exposure routes related to direct contact with groundwater are considered complete because GWTS maintenance workers could be exposed to impacted groundwater through dermal contact or incidental ingestion.

The outdoor worker scenario is designed to represent employees of commercial or industrial facilities within the study area who spend the majority of their workday outdoors. Consequently, pathways related to indoor air exposures are considered incomplete for outdoor workers. The primary exposure media for outdoor workers are soils and ambient air. Two potentially complete exposure pathways from direct contact with soils are incidental ingestion, and dermal contact. These direct contact pathways are assumed to be limited to surface soils. Outdoor workers could potentially be indirectly exposed to SRCs in soils via the inhalation route through fugitive dusts or volatile chemicals released into ambient air. Inhalation of volatile SRCs released from groundwater and migrating into ambient air is a potentially completed exposure pathway for outdoor workers. No completed pathways exist for direct contact with impacted groundwater because it is not used and is too deep for outdoor workers to encounter.

The construction worker scenario reflects temporary activities that could occur within the study area. The construction worker is assumed to be exposed to surface soils. In addition, it is assumed that the worker will be exposed to deep subsurface soils that may be exposed as part of excavation activities occurring at the Site. For this receptor, potentially completed pathways resulting from direct contact with soils are incidental ingestion and dermal contact. In addition, construction workers could potentially be exposed to SRCs in soil via the inhalation route through volatilization and from fugitive dusts released to ambient air through wind erosion or

soils handling. Inhalation of volatile chemicals released from groundwater is also a potentially completed pathway for the construction worker scenario.

7.1.2 <u>Residential Exposure Pathways</u>

Non-occupational exposures in the study area can occur onsite as a result of trespassing or off-site in the adjacent residential areas. The trespasser scenario is assumed to involve adolescent and teenage children from the nearby residential areas. The potential exposures associated with trespassing onsite would be infrequent and for a shorter duration than the assumed residential exposures. Potential direct contact with soil by trespassers could result in exposures through the incidental ingestion and dermal contact pathways. Inhalation exposures to chemicals in soils could occur via releases from wind erosion and soils handling, and from volatilization. Volatile chemicals released from impacted groundwater could also migrate into ambient air and contribute to the inhalation exposure. No other groundwater related exposures would be potentially complete for the trespasser scenario.

All other residential scenarios are assumed to take place in the off-site portions of the CSM study area. Fugitive dusts and volatiles released from onsite soils and transported to off-site residential areas via ambient air could result in potentially completed inhalation exposure pathways. Impacted groundwater could also contribute to potential exposure for the residential scenario through the inhalation route. Volatile chemicals released from groundwater could migrate through the vadose zone and into ambient air or infiltrate into indoor air. Vapor intrusion studies have been conducted in the downgradient area and the results will be submitted to NDEP under separate cover.

Currently, groundwater in the downgradient areas is not used for any consumptive purpose. There are, however, no legal restrictions that prevent use and groundwater could theoretically be used for consumptive purposes in the future. If so, residents could be exposed to chemicals in downgradient groundwater during use. This pathway is not considered likely given the generally poor overall consumptive quality of the regional groundwater, but is potentially complete. Residents also could be exposed to chemicals in offsite soils that have been transported from the site, such as dust transport. Exposures could occur via incidental ingestion or dermal contact. Finally, residents using water from Las Vegas Wash could theoretically

contact chemicals that have reached the Wash via groundwater discharge in the downgradient area.

7.2 ECOLOGICAL RECEPTORS AND PATHWAYS

Ecological receptors within the CSM study area are limited to the areas downgradient of the Site. No natural habitats exist onsite given the developed and industrial manufacturing operations at the Pioneer property (Section 3.6). Therefore, by agreement with NDEP, potential ecological receptors and exposure pathways can only occur in the downgradient area.

Potential wildlife exposures in fossorial or borrowing wildlife inhabiting offsite areas theoretically could directly contact near-surface groundwater during normal activities, but this exposure is expected to be negligible because animals will not inhabit or frequent subsurface areas that could be flooded by groundwater. Fossorial or borrowing wildlife, however, could also be exposed via inhalation to SRCs in subsurface environments that have volatilized from groundwater. Dermal exposures to volatilized SRCs could theoretically occur but would be negligible compared to inhalation exposures. Terrestrial wildlife inhabiting surface environments also could be exposed to SRCs volatilized from groundwater, but overall terrestrial wildlife exposure in surface environments would be negligible compared to that of fossorial or borrowing wildlife given the dilution and dispersion that will occur once SRCs reach ambient air.

8.0 SUMMARY OF CONCEPTUAL SITE MODEL

This section summarizes the CSM for the Site and study area. Figure 8-1 depicts the primary components of this CSM. This CSM was prepared based on historical and recent information compiled for the former Montrose and Stauffer facility operations, and downgradient area. The recent Site characterization data presented in this CSM consists of field and validated laboratory data generated during soil and groundwater investigations conducted by the Companies in 2006 and 2007. These investigations form the primary basis of this CSM.

This CSM was prepared in general accordance with the ASTM Standard for development of a CSM (ASTM, 2003). This CSM includes the following components of a CSM as outlined by the standard:

- Description of Study Area;
- Physical Setting and Nature and Extent of Chemicals;
- Transport Mechanisms;
- Remedial Actions (GWTS, SVE, and capping operations);
- Exposure Pathways and Potential Receptors;
- Summary of CSM, and
- Evaluation of Data Gaps.

This CSM presents the current understanding of Site and study area conditions. This CSM will be used to provide a basis for decisions to guide future investigative work and develop data to support the evaluation of potential future remedial options. The development of this CSM has been an iterative process and will be refined as additional data are available.

8.1 DESCRIPTION OF STUDY AREA

The Site is defined as the property currently owned and operated by Pioneer and formerly occupied by the Montrose and Stauffer facilities which are administratively separate and distinct from current Pioneer operations (Figure 2-1). Environmental conditions at the former Stauffer

facility are being addressed jointly by Pioneer and SMC/Syngenta and the former Montrose facility is being addressed solely by Montrose. The CSM study area includes the Site area and the downgradient area to Las Vegas Wash.

Montrose manufactured organic chemicals including chlorobenzene, polychlorinated benzenes, chloral, and 4,4'-dichlorobenzil at the Site from 1947 until 1983. Montrose ceased operations at the organic chemical plant in 1983 and demolished the plant in 1984. Montrose also manufactured HCL as a by-product of the organic chemical manufacturing process. Montrose continued HCL manufacturing operations until 1985 when the plant was leased to Pioneer. Pioneer purchased the HCL Plant in 1997 and continues to operate the plant as of this report date.

Stauffer manufactured chlorine, sodium hydroxide, HCL and agricultural chemical products at the Site from 1945 through 1988. The agricultural products included various pesticides and products for the formulation of pesticides and herbicides.

Pioneer currently operates chlor alkali production facilities at the Site and manufactures liquid chlorine, caustic soda, HCL, and bleach. Pioneer has operated the Site since 1988 following the transfer of ownership from Stauffer.

The former Montrose and Stauffer manufacturing processes generated various types of waste streams. These waste streams included organic compounds consisting of VOCs, SVOCs, OCPs, PCBs, and pesticide by-products; organic and inorganic acids; caustic water, and chlorine cell waste materials. These waste streams were managed in several onsite and areas (Figure 2-2).

The BMI Landfill is located adjacent to the northern boundary of the Site. The BMI Landfill is a former waste disposal facility common to the BMI Complex that received wastes from 1942 until it was closed and capped in 1980. The BMI Landfill included two lobes, a northern and southern lobe separated by the Slit Trench Area. Periodically between 1970 and 1980, undocumented process and office waste were also disposed of in slit trenches south of the landfill (Section 2.2.1; Figure 2-2). The future CAMU incorporates the Slit Trench Area and the Area to the west and south of the southern lobe of the BMI Landfill.

In 1994, NDEP identified numerous study areas at the Site for environmental investigation (designated as LOU study areas). These LOU study areas are typically associated with former manufacturing, materials storage, and waste disposal areas that may have produced some of these waste streams, and as such, are considered the primary source areas for soil and groundwater contamination. The Montrose LOU study areas have been grouped geographically and are located in within the Former Plant Site, the Closed Ponds Area, the Former Tank Farm Area, and the Former Benzene Storage Tank Area. The Stauffer and Pioneer LOU study items include former facilities related to the ACD operational areas, lindane production and associated BHC cake wastes, the Former Cell Renewal Building Area and Associated Conveyance Facilities, the Inactive Benzene USTs, and active and inactive CAPD Ponds (Figure 2-2).

8.2 PHYSICAL SETTING AND NATURE AND EXTENT OF CHEMICALS

Site assessment activities associated with the LOU study items are conducted under Consent Agreements with NDEP. Site assessment activities conducted to date have focused extensively on soil and shallow groundwater characterization at both the former Montrose and Stauffer facilities. Site assessment activities performed in 2006 and 2007 included comprehensive soil and groundwater analyses for a broad suite of SRCs, which were formally established in 2006. The SRCs were compiled based on a review of chemicals potentially present at the Site as raw materials, products, and wastes. SRC lists were developed individually for Montrose and Stauffer; however, the CSM considers the combined list for both former facilities.

Site data indicate that SRCs have impacted soil beneath the former facilities (Figure 8-1). Surface and subsurface soil in the vicinity of former Montrose and Stauffer operational areas contain concentrations of VOCs, SVOCs, OCPs, and metals above Industrial PRGs. The presence of these compounds in the soil is the result of accidental spills, leaks, and waste handling procedures at the Site in the past. An SVE system has operated since 2004 at the Montrose Former Plant Site to remove VOCs from impacted soil.

Groundwater beneath the Site occurs in the alluvial aquifer and Muddy Creek Formation and flows generally south to north towards Las Vegas Wash (Figures 3-4 through 3-11). Two zones have been identified within the Muddy Creek Formation: the UMCf and the UMCc. The alluvial aquifer is predominantly composed of unconsolidated silt, sand, gravel, and cobbles where present within alluvium; and of clay, silt, and fine-grained sand where present within the

transition zone or upper portions of the Muddy Creek Formation. The alluvial aquifer is typically only a few feet thick in the southern portion of the Site, increasing in thickness and becoming overall coarser to the north in the area of the GWTS. The UMCf consists predominantly of unconsolidated to semi-consolidated silt and clay, with occasional thin interbeds of fine- to medium-grained sand with silt and gravels. The UMCc is generally composed of well-graded sand and clayey sand. Groundwater in the vicinity of the Site is not considered a source of potable water.

8.3 <u>TRANSPORT MECHANISMS</u>

Site data indicate that SRCs have impacted alluvial aquifer and UMCf groundwater at concentrations above MCLs (Figure 8-1). SRCs are not currently detected in the UMCc based on recent sampling data. Advective transport of dissolved SRCs in the alluvial aquifer groundwater, the primary transport mechanism, has resulted in a plume that extends from the source areas to Las Vegas Wash. SRC concentrations in alluvial aquifer groundwater are highest beneath the former source areas and decrease with distance from the source areas towards the north. The GWTS, which is located about a mile north of the source areas and has operated since 1983, effectively removes organic SRCs from the alluvial aquifer groundwater, as demonstrated by the limited extent and low concentration of these SRCs in the downgradient area. Inorganic constituents and selected BHC isomers exist in the alluvial aquifer in the downgradient area.

SRCs exist in the UMCf groundwater at concentrations above MCLs as a result of DNAPL migration. DNAPL composed predominantly of VOCs exists in the vadose zone, alluvial aquifer, and UMCf beneath and downgradient of the former Montrose facilities. Details on NAPL transport are included in Section 5.2. The DNAPL materials exist as a residual mass; unevenly distributed in the soil matrix in the form of disconnected blobs and ganglia to a depth of approximately 120 feet bgs. Elevated concentrations of dissolved-phase SRCs are detected in the UMCf downgradient of the Site. Further investigation of the horizontal and vertical extent of DNAPL is presently being conducted.

8.4 REMEDIAL ACTIONS

Remedial actions initiated by Montrose and/or Stauffer and Pioneer within the CSM study area include: 1) the construction and operation of the GWTS; 2) the installation of an SVE system in the western portion of the Montrose Former Plant Site (Figure 2-2); 3) the placement of an asphalt cap over the Former ACD Plant, Former Lindane Plant, and Former BHC Cake Piles 1 and 2, and 4) the placement of clay covers over BHC Cake Pile 3, the ACD Drum Burial Waste Management Area, and the Former Leach Field and Phosphoric Acid Pond/Trenches.

The GWTS is located north of the former Montrose and Stauffer facilities and south of the downgradient area (Figure 2-1). The purpose of the GWTS is to extract and treat contaminated alluvial aquifer groundwater migrating northward from the former Stauffer and Montrose facilities and BMI Landfill areas. Contaminated groundwater is extracted from the alluvial aquifer by 13 extraction wells. The treated groundwater is then returned to the alluvial aquifer downgradient of the extraction wells via three below-grade recharge trenches (Figure 2-1).

The SVE system includes four VEWs and an aboveground piping network and extracted vapor is treated using GAC located within a treatment system compound located at the Montrose Former Plant Site (Figure 2-4).

Stauffer constructed an asphalt cap over an approximately six-acre area of the Site, including the Former ACD Plant, Former Lindane Plant, and Former BHC Cake Piles 1 and 2. The asphalt cap serves to limit the amount of infiltration and reduce potential exposure pathways at these areas of the Site (Figure 2-2).

Soil covers consisting of a one-foot thick clay cover overlain by approximately one foot of native sand and gravel deposits were installed over BHC Cake Pile 3, the ACD Drum Burial Waste Management Area, and the Former Leach Field and Phosphoric Acid Pond/Trenches (Weston, 1993) (Figure 2-2).

Other groundwater remediation systems are present in and near the CSM study area. Tronox maintains three groundwater remediation systems designed to capture and treat shallow

groundwater containing elevated concentrations of chromium and perchlorate. The remediation systems utilize fluidized bed reactor methods to remove perchlorate and iron reduction to remove hexavalent chromium from groundwater (ENSR, 2005). The location of the Tronox remediation systems are presented in Figure 2-1.

AMPAC also operates two groundwater remediation systems to capture and remediate shallow groundwater containing elevated concentrations of perchlorate. The AMPAC remediation systems utilize in-situ bioremediation to remove perchlorate from impacted groundwater. The locations of the AMPAC remediation systems are presented in Figure 2-1.

8.5 EXPOSURE PATHWAYS AND POTENTIAL RECEPTORS

The Site area is and has been used exclusively for industrial purposes. The Site is expected to continue as an industrial Site in the future. Land use downgradient of the Site includes both industrial/commercial and residential areas. Residential and worker populations were considered in the exposure pathway analysis. Potential receptors include indoor and outdoor workers, trespassers, and offsite residents. Based on the exposure pathway analysis, several potentially complete exposure pathways were identified (Figure 7-1).

9.0 EVALUATION OF DATA GAPS

An evaluation was performed to identify meaningful data gaps that affect assessment of complete human and ecological exposure pathways and the evaluation of the need for any future additional characterization and remedial action. The following data gaps are identified at this time:

1. The horizontal and vertical extent of selected SRCs, including OCPs in Site soils has not yet been completed and is recognized as a data gap. To further characterize the distribution of OCPs in shallow soils and provide additional data to support development of a site-specific risk assessment, the September 6, 2007 *Work Plan Addendum II – Shallow Soil Investigation* (PES, 2007d) has been prepared on behalf of Pioneer and SMC/Syngenta, and approved by NDEP for implementation.

2. It is recognized that the current physical characteristics of the soil covers at Stauffer BHC Cake Pile 3, the ACD Drum Burial Waste Management Area, and the Former Leach Field and Phosphoric Acid Pond/Trenches, need to be confirmed. To verify the current physical characteristics of the soil covers and to facilitate future evaluations of these waste management areas, the May 31, 2007 *Work Plan for Assessment of Soil Covers* (PES, 2007c) has been prepared on behalf of Pioneer and SMC/Syngenta, and approved by NDEP for implementation. The results from the subject scope of work will be used to document the specification of the soil covers at these waste management areas.

3. The lateral and vertical extent of dissolved-phase SRCs in alluvial aquifer groundwater are not fully delineated along the eastern boundary of the Pioneer property The eastern extent of SRCs is needed to determine if any SRCs associated with the Site are migrating to the east and potentially bypassing the GWTS. Additional monitor wells and groundwater sampling are needed in the western portion of the Tronox property to characterize the extent of the alluvial aquifer and extent of benzene, chlorobenzene, chloroform, 1,4-DCB, alpha-BHC, and gamma-BHC. Tronox has prepared a workplan to address alluvial aquifer groundwater conditions in the northern portion of the Tronox site (ENSR, 2008). In addition, Montrose has proposed additional monitor wells to be located north and east of the Montrose Closed Ponds Area (Geosyntec, 2008). Data obtained by the implementation of these two workplans are expected to yield pertinent information regarding the nature and

groundwater quality of the alluvial aquifer along the CSM study area/Tronox property boundary.

4. The vertical characterization of SRCs in groundwater downgradient of the Stauffer Former Leach Field and Phosphoric Pond/Trenches and Former Wastewater Pond 1 (i.e., CAPD Pond 7) is identified as a data gap. The approach and objectives for additional vertical characterization of groundwater conditions below the alluvial aquifer (i.e., within the Upper Muddy Creek Formation) in these areas, will be developed based on future technical discussions with the NDEP.

5. The presence of dissolved-phase SRCs in the UMCf in the immediate area of the GWTS and the effectiveness of the GWTS to potentially capture these SRCs, if present, has not been determined. Additional UMCf monitor wells are needed upgradient and downgradient of the GWTS to determine if SRCs are present above MCLs and to characterize the hydraulic relationship between the alluvial aquifer and the UMCf relative to the operation of the GWTS.

6. To date, activities to evaluate the performance of the GWTS to provide adequate hydraulic capture have included extensive groundwater sampling programs based on both the Stauffer and Montrose comprehensive lists of SRCs, the interpretation of groundwater quality data, and the assessment of overlapping cones of depression as specified in the 1983 Consent Order (H+A, 2007c). To further evaluate hydraulic capture of the GWTS, additional studies should be performed which are based on multiple converging lines of evidence.

7. The lateral and vertical extents of DNAPL in the UMCf are not fully delineated along the eastern-central boundary of the Pioneer property (Figure 4-43). The installation of additional reconnaissance soil borings and monitor wells are pending as of the publication date of this CSM in this area. A contingency drilling program will be used so that additional borings and wells can be drilled to complete the delineation of DNAPL efficiently. Completion of this program is necessary to fully understand the character, extent, and migration potential of the DNAPL, for evaluation as a source of chemicals to the alluvial aquifer, UMCf, and the GWTS. This information is necessary to evaluate the need for potential future targeted remedial actions.

8. Background concentrations of selected SRC's in soil (greater than 10 feet bls) and alluvial aquifer groundwater have not been fully evaluated for the Site. This is a potential data gap.

The need for background data for deep soils and alluvial aquifer groundwater is not yet clear. If such background data is identified as necessary for the RAS process, then existing site data, the data of other BMI Company programs and regional data will be used to evaluate the issue.

9. The presence of an upward pressure gradient between the Upper Muddy Creek Formation and the alluvial aquifer needs to be fully evaluated for the Site. This evaluation will take place within the groundwater Remedial Action Study for the Site.

10. It is recognized that the current nature and extent of contamination at the Stauffer Site due to windblown deposition has not been fully delineated. A workplan has been submitted to address this issue (Integral, 2008). In addition, the data from the BRC Perimeter Monitoring Plan will be compiled, reviewed and incorporated into the plan of action.

The details of additional Site characterization to address these data gaps will be outlined in workplans, as appropriate. Studies by others near the Site may provide information that would reduce the extent of, or eliminate, some of the above data gaps.

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